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**Abstract**

The major objective of this thesis is to quantify the trans boundary shipment data for the solid biomass waste in Europe for the years 2010 – 2015. The thesis discusses the major importers and exporters of solid biomass waste especially hazardous as well as non hazardous wood waste in Europe, the current as well as future trends in this sector, the trade maps and key drivers of the import and export of solid biomass waste. It further discusses the key drivers such as the legislations surrounding the trans boundary shipment of waste in the EU and its individual member states and capacity factor of the wood waste to energy industries established in the EU countries. Finally, it analyzes the primary energy supply of the imported wood waste in every country and its contribution in the bioenergy supply in the energy share of a country. The time period of the study is chosen from 2010 till 2015. The countries which are actively participating in the shipment of the solid biomass waste majorly wood waste are chosen and are examined as individual cases.

**Keywords** Solid Biomass Waste, Wood Waste, Transboundary Flow, Trade Maps, Energy, EU, Hazardous, Bioenergy

# MASTER'S THESIS PROJECT

# TRANS BOUNDARY FLOW OF SOLID BIOMASS WASTE STREAMS IN EUROPE
## and its effect on the country's energy system


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# ABBREVIATIONS

| | |
|---|---|
| AbFG | Abfallbeseitigungsgesetz |
| AT | Austria |
| AVV | Abfallverzeichnis-Verordnung |
| BE | Belgium |
| CEWEP | Confederation for European Waste to Energy Plants |
| CH | Switzerland |
| CHP | Combined Heat and Power |
| CN | Combined Nomenclature |
| CSTB | Centre Scientifique et Technique du Bâtiment |
| DE | Germany |
| DIY | Do It Yourself |
| DK | Denmark |
| EC | European Commission |
| EEG | Erneuerbare-EnergienGesetz |
| EJ | Exajoules |
| EU | European Union |
| EUTR | European Union Timber Regulation |
| EWC | European Waste Catalogue |
| FI | Finland |
| FR | France |
| HS | Harmonized System |
| IEA | International Energy Agency |
| INERIS | National Institute for the Industrial Environment and Risks |
| ISWA | International Solid Waste Association |
| KT | Metric Kilo Tons |
| kWh | Kilo Watt Hour |
| MDF | Medium Density Fibreboard |
| MJ/kg | Megajoules/Kilogram |
| MSW | Municipal Solid Waste |
| MW | Megawatt |
| NL | The Netherlands |
| NO | Norway |
| NWMP | National Waste Management Plans |
| OSB | Oriented Strand Board |
| PJ | Petajoules |
| SE | Sweden |
| UK | United Kingdom |
| US | United States |
| WFD | Waste Framework Directive |
| WID | Waste Incineration Directive |
| WRA | Waste Recycling Association |
| WW | Waste Wood |

# EXECUTIVE SUMMARY

The world is facing one of its major waste management problem in the 21st century. According to International Solid Waste Association (ISWA), the global urban waste generation levels are increasing every year estimating at 7 to 10 billion tons per year. The proper disposal and recovery of waste is a prime concern in various countries worldwide. The increase in technological advancements has now ensured better ways to recover the best out of the waste. Strong legislative bodies and regulations are also helping to curb the problem, especially in the European Union (EU).

Although, the first step in a sound and secure waste management system is proper quantification of data regarding the generation, trade as well as disposal methods of the waste. Although, Basel Convention requires the member countries to provide with yearly national reports for the trans boundary shipment of waste yet there lacks a consolidated approach towards a holistic picture of shipment of waste in the world. Since, waste is being increasingly used as a feedstock for energy purposes, competing with traditional fuel types as well as biomass sources. Hence, a proper quantification of solid biomass waste would be beneficial for industries as well as countries for proper and faster disposal. This report aims at quantifying the existing data on the trans boundary shipment of solid biomass waste in north western Europe during the years 2010 till 2015 in the form of trade maps and analyze the underlying key drivers behind the shipment of waste.

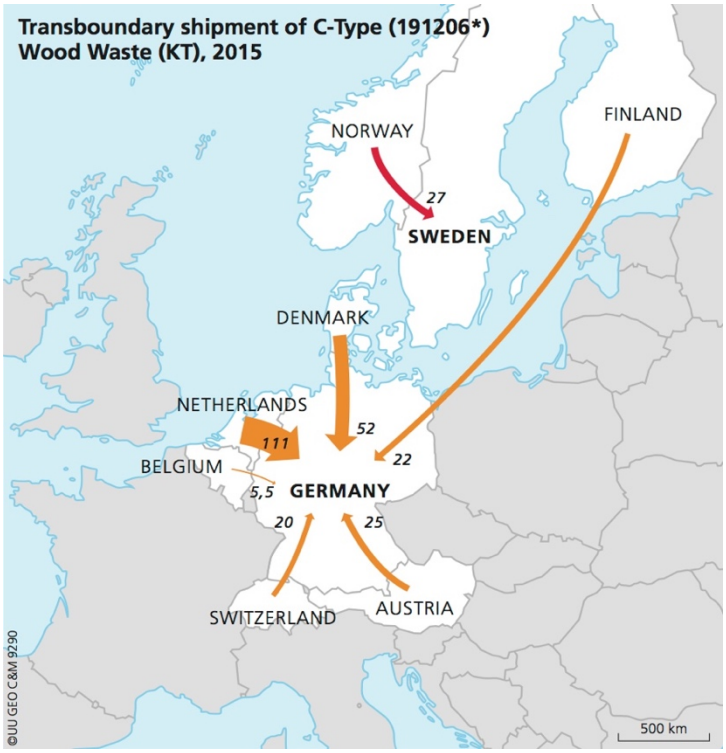
The report focuses on trans boundary shipment flows of solid biomass waste particularly wood waste (hazardous and non hazardous) in the north western part of Europe in the years 2010-2015. The wood waste is a cheaper alternative fuel as a replacement for biomass and hence an analysis of its trans boundary shipment can be helpful for the national plans of the countries involved as well as the industries and organizations. The study chose the European Waste Codes (EWC) to shortlist the type of wood waste. The EWC narrowed down to mainly 191206* (hazardous wood waste) and 191207 (non hazardous wood waste) which have considerable shipment flows in Europe. The wood waste is being used for producing energy in modern bioenergy plants in Germany, The Netherlands and Sweden. The main importers of both hazardous and non hazardous wood waste are Germany and Sweden with a yearly import of 600+ Kilo Tons (KT). The Netherlands also imports non hazardous wood waste from UK and Belgium for the feedstock of its bioenergy plants. The main exporters of non hazardous wood waste are UK, The Netherlands and Norway. The combined exports exceed 800 KT every year. The major exporter for hazardous wood waste is The Netherlands with a yearly average of 100 KT to Germany.

The general trend of total shipment of non hazardous wood waste is increasing every year since 2010. The non hazardous wood waste is in demand because of its industrial grade nature and cheaper price than regular biomass. The hazardous wood waste shipments are generally declining since 2010 due to stricter legislations that requires the countries to take responsibility of the hazardous waste that it is producing.

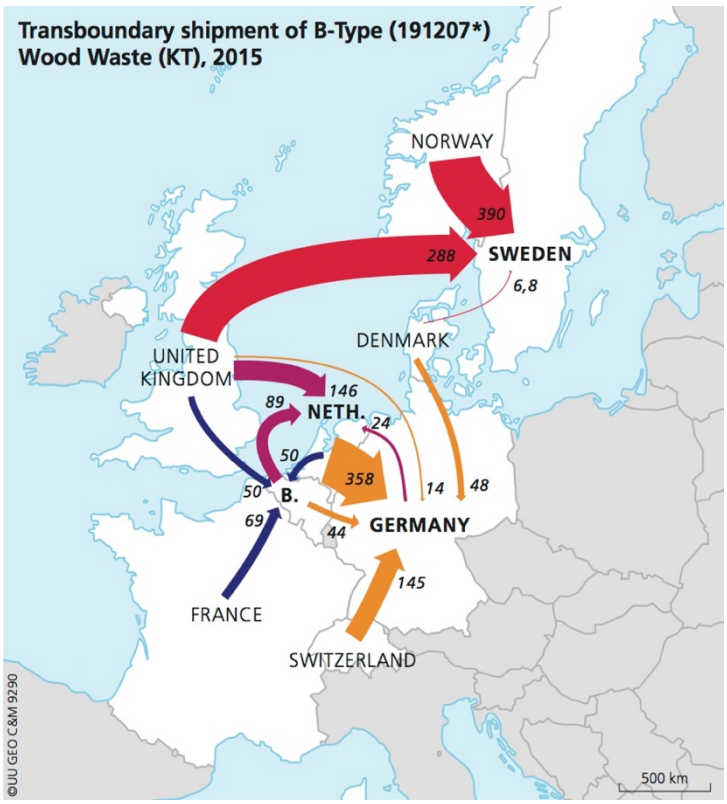
The key driver for both hazardous and non hazardous wood waste is found out to be legislation and policies, which differs in different countries as investigated in this report. The support provided by an elaborate legislation and policies of a country can pave way for a better capacity to deal with hazardous as well as non hazardous wood waste, hence interlinking another driver. This is the case in Germany, where a detailed legislation was setup since 1990 regarding waste management and it introduced even detailed legislations and policies in the upcoming years

regarding trans boundary shipment of waste, Renewable Energy Sources act, circular economy of waste and management of wood waste, which helped in installation of bioenergy plants. In 2015, it had 700 biomass heating plants which produced 1510 $MW_{el}$ and hence requires a considerable amount of wood waste to run constantly throughout the year. (DBFZ, 2015) This makes Germany drive the trans boundary shipment of wood waste in Europe.

As seen in the figure on the right, Germany is the major importer of hazardous wood waste in Europe for the year 2015. The country is importing hazardous wood waste from neighboring countries like The Netherlands, Belgium, Denmark, Finland, Austria and Switzerland. The major reason is the lack of provision of hazardous waste handling in the legislation of the countries involved and if there is a provision, it is generally a costlier method, and hence transporting it to a different country, in this case, Germany is a better choice. Every year Germany imports approximately 250 kilo tons of hazardous wood waste. In the north, Sweden imports from Norway an estimated 25-30 kilo tons every year.




The non hazardous wood waste trans boundary flow occurs extensively in north western Europe. Germany and Sweden are the two major importers and UK and The Netherlands are the two major exporters of non hazardous wood waste. A total of 1722 KT of wood waste was traded in 2015, with Germany importing 633 KT and Sweden importing 685 KT. The non hazardous wood waste is mainly driven by the capacity factor in the respective countries.



# 1. INTRODUCTION

In the recent times, the world is facing some major problems ranging from ever increasing population, energy poverty, climate change to increase in global waste generation every year. The waste management issues started with the age of industrialization around the world. It aggravated due to the sudden increase in the population and consumerism. According to the report by International Solid Waste Association (ISWA), the global urban waste generation stands at 7-10 billion tons per year out of which only 30-40% is collected properly, which can lead to many health and environmental problems. (ISWA, 2014) Clearly, waste generation has been a persistent worldwide problem. The increasing waste and the lack of its management leads to public health issues and environmental degradation. In order to tackle these ill effects, various rules and regulations were set up all around the world, especially in the EU. These regulations have since been effective in controlling the situation in Europe. The regulations can be amended and new regulations are constantly formed to account for new problems that arise due to increasing waste generation.

In 2012, the EU generated 2514 million tons of total waste out of economic and household activities. From 2004 till 2012, the EU had a 10% increase in the hazardous waste estimated at 99.9 million tons in 2012. (Eurostat, 2016) The EU realized there could be a huge issue due to the increasing waste, especially hazardous. Hence, the EU laid down waste directives and regulations over the years, amongst which the directive 2008/98/EC holds a lot of relevance. It establishes the basic concepts of waste which includes various definitions of waste, generation, recovery and disposal as well as the waste hierarchy. According to the directive, waste is any substance or object a user discards. (The European Union, 2008) The major objective of the European Union was to turn the waste into a resource as a part of circular economy. This became a key driver to stimulate better waste management and innovation in material as well as energy recovery from waste in the EU. This led to sustainable usage of waste along with reduced health and environmental issues caused by landfilling of waste.

Since waste is a very broad term, it can be classified in many ways. A general classification which can differentiate between the waste is its hazardousness level. The waste can be divided into hazardous and non-hazardous waste. Hazardous waste is a waste that contains high quantity of elements which fall under the list of dangerous items and hence has to be reported with proper details to relevant authorities if it is being transported between countries. (European Commission, 2008) A non-hazardous waste does not contain dangerous elements and can be transported between countries without notification. Up till the 1990's, the world was facing a huge problem of hazardous waste generation estimated around 400 million tons per year and its inappropriate trans boundary shipment across countries. (Buff. L. Rev., 1991) Hence, the Basel Convention was formed to avoid any illegal disposal of hazardous waste to developing or poor countries. The convention was signed by the EU and 184 countries ensuring a better approach towards a controlled trans-shipment of hazardous waste across countries. Still, one of the major problems with the waste transportation was the quantification of data which was improved under the convention's national reporting database system, which required to submit specific details on import and export of various waste substances of all the member countries.

In the EU, hazardous waste is primarily shipped between the member states. The hazardous waste shipments peaked in 2007 in the EU at around 8.1 million tons. Since then, there has been a 23% decrease in shipment of hazardous waste in the EU, due to the financial crisis of 2008, but generally the hazardous waste generation is increasing in the EU. (European

Environment Agency, 2012) Majority of hazardous waste shipment leads to reclamation of metal compounds or incineration with or without energy recovery in the EU. 93% of the hazardous waste exports was shipped between the member states of the EU. Some of the major hazardous waste streams are soil and stones containing dangerous substances, solid waste from gas treatment, lead batteries and hazardous wood waste. Hazardous wood waste was one of the top five transported waste streams in the EU standing at 203 KT in 2013. (EUROSTAT, 2013)

Since the EU is focusing on increasing the share of renewables in the energy share and biomass contributes fairly to the energy share of many countries in the EU, industries and traders are highly dependent on different types of feedstock of biomass. Even though, wood chips are used in many industries, with the increase in the shipment of wood waste, there are industries emerging in countries like the UK, The Netherlands, Germany and Sweden which are recovering energy from wood waste. Traders are also interested in the shipment of wood waste primarily because of its low prices which gives it a better edge over the conventional biomass like wood chips. Since there is a general interest developing in energy recovery from waste, this report essentially focuses on the quantification of the data in the form of trade maps for solid biomass waste stream such as the hazardous wood waste as well as the non-hazardous wood waste in Europe during the years 2010 – 2015, hence fulfilling the knowledge gap that exists in the area of wood waste market in Europe. Even though, there have been individual country reports, a specific study on the wood waste flow in Europe would be helpful to the waste management stakeholders, energy markets, energy industry and governmental bodies for a concise documentation of the European wood waste market.

# 2. OBJECTIVE

The major objective of this thesis is to quantify the trans boundary shipment data for the solid biomass waste streams in Europe for the years 2010 – 2015. The thesis discusses the major importers and exporters of hazardous and non-hazardous wood waste in Europe, the current as well as future trends in this sector, the trade maps and key drivers of the import and export. It also details the legislations surrounding the trans boundary shipment of waste in the EU and its individual member states. Finally, it analyzes the primary energy supply of the imported wood waste in every country and its contribution in the bioenergy supply in the energy share of a country. The scope of the thesis is based on various factors such as time, location and type of waste. The time period of the study is from 2010 till 2015. The countries which are actively participating in the shipment of the solid biomass waste are chosen and are examined as individual cases. The type of waste is chosen on the basis of availability of data.

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# 3. METHODOLOGY AND DEFINITIONS

## 3.1. METHODOLOGICAL APPROACH

The study has chosen a bottom up approach of research methodology. The study started with research on The Netherlands and its import and export of solid biomass waste and the same methodology of data collection and research was then applied to the other major countries identified as the importer and exporter of hazardous and non-hazardous wood waste. The research methodology is explained in detail in the following chapter.

Initially, an overview of established research on the subject was performed. Articles based on the trans boundary shipment of waste on an international level as well as European level were studied in great detail. The overview also considered the research done on the types of wood waste and municipal solid waste and its physical and chemical properties as well as the key drivers involved in the import and export of waste in general. This helped in laying down a basis for the study and understanding important concepts regarding trans boundary shipment of waste. Since, the research was performed at Utrecht University, The Netherlands was chosen as the first country for identifying the trade routes of solid biomass waste streams in Europe.

In the beginning of the study, two waste streams were chosen, municipal solid waste and post-consumer wood waste. As the study progressed, it was narrowed down to wood waste. The major reason to choose wood waste was to have a proper quantification of data in the form of trade maps since there were fewer studies related to wood waste. Also, wood waste as a fuel has grown interest in a lot of countries like UK, The Netherlands, Germany as well as Sweden and it competes directly with the conventional biomass fuels like clean wood chips because it is a cheaper fuel, hence a better understanding of the trade routes would enable greater acceptance in other countries as well as countries dealing with the trade of wood waste in a huge quantity.

Online databases were recognized for the statistics available for the solid biomass waste streams of The Netherlands. The statistics were obtained from individual countries national databases, traders, industries as well as international databases like EUROSTAT and Basel International National Reports. Once the major importer and exporter countries were identified for The Netherlands, the next logical step was to identify a code system that represented the waste streams for easy identification and availability of data. The code system varies widely in Europe and on an international level. The various code systems encountered during the data collection were as follows:

- Combined Nomenclature (CN) Codes: The CN codes are a tool for classifying goods for intra EU trade which is maintained by Eurostat. It is an 8-digit code number which has layers of explanation and detail of products being traded. (European Union, 2016)
- European Waste Codes (EWC): CN codes are not specifically designed for waste products and hence, an increasing attention towards the waste products led to EWC list. EWC list is a reference nomenclature specifically for providing a common terminology for the different types of waste. (European Union, 2000)
- Y – Codes: The Basel Convention defined different types of waste, hazardous as well as non-hazardous waste in the form of Y – Codes which is provided in detail in the Annex I of Basel Convention. (UNEP, 1992)

Initially, the data was collected corresponding to the CN codes of wood waste and MSW for The Netherlands. The EWC is also being used by extensively by European countries and though HS and CN codes are also used by the European countries, they are not updated as regularly as EWC. The Basel Convention reports demand the information in Basel Codes or Y – codes. The definitions of the waste streams are very general for the Y – codes and hence it is not reliable. (Christian Fischer, 2012) Due to the presence of different code systems, it was a bit difficult to choose a single and uniform system for data collection. Finally, after a lot of consultation from experts in Europe, a common code system for Europe's waste called European Waste Code (EWC) list was adopted due to better reliability of the data source.

After the data was collected from online databases and sources for waste wood, multiple interviews were held with ministries, traders and industries for co – relating data between the three and getting a reliable dataset for The Netherlands. A basic outlay of trade routes of The Netherlands was generated on a map and then the same methodology was used for other key countries involved in the export and import of hazardous as well as non-hazardous wood waste in Europe.

All the countries examined for the purpose of this study submitted EWC along with the Y – codes in the national reports of Basel convention and it made the data collection process easier and straight forward. Hence, Basel Convention National Reports were ultimately used extensively.

To identify major key drivers of trade of wood waste, an intensive questionnaire was designed for IEA Bioenergy Task 36 and Task 40 which can be referred to in the annex. The feedback to the questionnaire was helpful to narrow down the key drivers for trans boundary shipment of wood waste in Europe.

## 3.2. DATA COLLECTION

Primary data used is from national reports and official statistics to maintain a level of relevance in the study. If the official data wasn't available, data from reports or publications was used. Data was confirmed from various telephonic conversations with experts in the field of wood waste trade.

The main sources were:

- National reports: These statistics were provided by the ministries with data on production, trans boundary shipment and end use. The data was also obtained from Basel International's national reports of every member country of the Basel convention. These two data sources were supposed to be of prime importance and relevance since the data in Basel Conventions' reports was updated with EWC as well as Y codes. Basel Codes or Y – codes were not a reliable source, but since every country that has been examined also provided the data with corresponding EWC, the data collection became easier and straight forward. (Christian Fischer, 2012)

- EUROSTAT and European Commission: The data available on the EUROSTAT was available in the form of Combined Nomenclature (CN Codes) and there was slight co relation between EWC and CN codes data. The CN codes are used for the intra EU trade and have an elaborate description for every commodity that is traded. The EWC

list is specifically designed for the waste being traded in the EU and it provides as better statistical dataset than a general coding system applicable to every traded commodity.

- Statistics from consultancy companies: Data was also provided by various consultancy companies in different parts of Europe in the form of published reports in their national language. Consultancies in The Netherlands has published multiple reports on the wood waste market and the drivers responsible for it. UK based consultancies like Anthesis and Poyry have also been publishing reports regarding the wood waste market in the UK.

- National Waste Management Plans: The national waste management plans were consulted for the legislations and regulations applied in the individual countries. Every country has a dedicated waste management plan which ultimately decides future plans for the different type of waste generated and traded.

- Reports and researches by academicians and industries: The researches were useful to define the basic terms and background information needed for the conducting the thesis.

## 3.3. BOUNDARIES

The scope of the thesis can be very vast if some boundaries are not chosen accordingly. The process of choosing boundaries depended upon the availability of data. The boundaries were chosen in multiple areas. The boundaries of the thesis can be divided as follows:

- Countries: The countries selected for the thesis are The Netherlands, Germany, Sweden and UK. The major focus is on these countries since majority of wood waste trade is encountered by them.

- Waste stream: The study started with a focus on Municipal Solid Waste as well as Wood waste. With the progression of the study, wood waste was favored. The wood waste also occurs in different formats. The study is concerned majorly with the post-consumer wood waste. These are the waste streams finally shortlisted for the thesis:
    - 191206*: The mechanically treated wood waste that is also known as hazardous wood waste
    - 191207: Wood waste other than 191206*.
    - 171201: Wood waste from Construction and Demolition Waste
    - 200137*: Hazardous wood waste from household waste
    - 200138: Wood waste other than 200137*

- Time Period: The time period of the study is chosen to be 2010 – 2015. The main reason being the changes in legislation in 2008 and hence a more defined statistics structure for the trans boundary shipment of waste.

- End Use: The biomass waste streams are also chosen on the basis of its end use. The biomass waste stream with its end use as energy recovery is preferred and is of main interest in this report as compared to material recovery or recycling.

## 3.4. BACKGROUND

This part of the chapter talks about the basic definitions of the wood waste and its origins. It also talks about the different EWC present in the database which refer to the hazardous as well as the non-hazardous wood waste.

Wood waste can be formed during a lot of processes like wood harvesting, wood processing, and also at the end of final use like post-consumer or production waste. The wood waste from harvesting or wood processing is relatively clean and comes under the EU Timber regulations. It contains more than 50% wood and is also known as industrial wood waste. On the contrary, the post-consumer wood waste refers to the used wood which are at the end of its life. The wood does not have any further application and hence is subjected to either recycling or energy recovery. Post-consumer wood waste accounts for around 22% of used raw material for wood purposes, 9% for industrial purposes and over 12% for energy use. (Mantau, 2012)

The wood waste can originate from different sectors and hence are divided accordingly in the European Waste Code (EWC) list. The different types of wood waste that are present in the EWC are:

Table 1: EWC of types of wood waste *(European Commission , 2000)*

| EWC | Category | Description |
|---|---|---|
| **171201** | Construction and Demolition Waste | Wood<br>- Chairs<br>- Hardboard<br>- Railway Sleepers<br>- Untreated Timber<br>- Wood Cuttings |
| **191206*** | Materials from Mechanical Treatment of Waste (Sorting, Crushing, Pelletizing) | Wood containing hazardous substances<br>- Treated Timber<br>- Wood<br>- Wood Cuttings |
| **191207** | | Wood other than 191206*<br>- Chairs - wooden<br>- Pencils<br>- Timber - untreated<br>- Wood<br>- Wood cuttings |
| **200137*** | Municipal and Household Waste | Wood containing dangerous substances<br>- Civic amenity waste<br>- Timber - treated<br>- Wood<br>- Wood cuttings |
| **200138** | | Wood other than that mentioned in 20 01 37<br>- Civic amenity waste<br>- Cork<br>- Pencils<br>- Timber - untreated |

As it is evident in the Table 1, the wood waste can be categorized on the basis of hazardousness. The wood, being organic in nature, are reactive to their surroundings. In some cases, the wood has to be preserved for longer period of time and hence various chemical preservatives are used to prolong the lifetime of the wood, which also makes the wood and the wood waste occurring from the same, hazardous in nature. There are two major practices for increasing the quality and lifetime of the wood (CSTB, 2005):

- Basic treatment of the surface with substances which do not penetrate the wooden body such as gluing or coating of paint.
- Proper preservation treatments where in the wood is treated with chemicals to make the wood inert to its surrounding.

These are all the different type of treatments that can be done on the wood:

Table 2: Different methods of wood treatment and their hazardousness levels

*(INERIS, 2006) (CSTB, 2005)*

| Treatment | Function | Preservatives/ Chemicals used | Hazardousness of the Preservative/ Chemical |
|---|---|---|---|
| **Thermal Treatment** | Protection | None | None |
| **Coating** | Protection and beautification | Nonmetallic varnish or paints | None |
| | | Metallic varnish or paints | Toxic, if concentration is high |
| **Gluing** | Assembling | Mineral Glue, Animal Glue | None |
| | | Synthetic Resins | Toxic, Noxious |
| **Fire Proofing** | Fire Protection | Metallic Salts, Isopropanol | Toxic, if concentration is high |
| **Preservation by Soaking** | Resistant to medium biological attacks | Boron and other heavy metals | Toxic, if concentration is high |
| | | Diazole, Pyrethroide, IPBC | Irritating, hazardous for reproduction |
| **Preservation by Impregnation** | Resistant to high biological attacks | CCA, Arsenic, Organic Copper, Creosote | Carcinogenic, irritating, highly hazardous |

Based on the hazardousness described above, the wood waste can be further categorized as:

- Clean Wood Waste
- Moderately Treated Wood Waste
- Highly Treated Wood Waste

### 3.4.1. Clean Wood Waste

Clean wood waste can be classified as the wood waste that is not subjected to any sort of chemical treatment. They might have received a mechanical or thermal treatment. They are graded as non-hazardous wood waste and can be used as biomass with proper licensing. For example, in the case of waste from construction and demolition, the wooden packaging is the clean wood waste and can be used for energy as well as material recovery. (WRAP (Waste & Resources Action Programme, 2012) The example of EWC that is prevalently used for clean waste wood is 150103 (wooden packaging).

Figure 1: Clean Wood Waste. (Source: RPS)

### 3.4.2. Moderately Treated Wood Waste

These wood waste have a slight concentration of preservatives in them, which are not deemed harmful. It can be wood material that has a coating or glue on them. Since, the layer of preservatives on the wood is still dangerous, a certain threshold is mentioned in the regulations to make sure that it does not cross over to highly treated wood waste, in which case the end use of the wood would differ a lot. The EWC such as 191207, 170201 and 200138 can be categorized as moderately treated wood waste.

Figure 2: Moderately Treated Wood Waste

The wood waste in this category are a mix of hazardous as well as non-hazardous waste and since it is very difficult to analyze the concentration of the hazardous substance in the wood waste because of lack of chemical analysis and the sheer amount of waste that is being produced, it gets difficult to sort them correctly. Hence, better regulations are needed to get a clear demarcation between hazardously dangerous wood waste and clean wood waste. (CSTB, 2005)

### 3.4.3. Highly Treated Wood Waste

These types of wood waste generally arise from wood that is subjected to heavy outdoor usage and hence needs to be heavily protected from the surroundings. The wood is coated and impregnated with chemical preservatives which are ultimately ingrained and practically part of the wood. These are more commonly known as highly treated wood waste (Kurata, 2005). Due to the high level of hazardous substance, the treatment is limited to incineration or hazardous landfill sites, if proper licenses are acquired. The EWC with an asterisk indicate hazardous wood waste and hence 191206* and 200137* are both considered harmful and highly treated wood waste.

Figure 3: Treated Wood Waste

## 3.5. LEGISLATION

### 3.5.1. EU LEGISLATION

The European Union establishes directives and regulations for the member states involved. A directive is not legally binding but is created to give insights on results that are needed to be achieved by the member states. The EU has generated various directives to keep the generation and trade of waste in check. The directives make it easier to form a common minimum expectation from each country. The countries can henceforth apply better legislative policies in their own country once they have fulfilled the bare minimum mentioned in the directives of EU. The Waste Framework Directives aims at converting the EU into a recycling society. The WFD also generated a waste hierarchy to inform more about the end use of waste. On the other hand, regulations are legally binding rules that the EU Member States agree upon after consensus. A regulation has a binding legal force that every member state has to follow and it is put into force on a particular date all across the EU.

Apart from the EU directives and regulations, there are international treaties such as Basel Convention that helps to reduce the trans boundary shipment of hazardous waste around the world, especially preventing the flow from developed nations to less developed and developing nations. The Lisbon treaty also promotes sustainable development in Europe properly. This treaty works majorly on the "polluter pays price" principle.

### 3.5.2. EU DIRECTIVES AND REGULATIONS

- Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste

  This directive was introduced to regulate the landfilling of waste in EU. Its major aim was to reduce or prevent the landfilling in the EU and thereby reducing the ill effects associated with it. The directive also defined different categories of waste such as municipal waste, hazardous waste, non-hazardous waste and inert waste. The landfills were also categorized in three different categories: landfill for hazardous waste, landfill for non-hazardous waste and landfill for inert waste. It also makes it mandatory for the member states to reduce their biodegradable waste going in the landfill by 75% by 2006 and 35% by 2016 and to be treated before disposal. The directive ensures which waste can be disposed off in landfills. This directive is one of the major reasons that the EU is going towards a circular economy regarding waste. The directive makes it easier to push the market towards an energy recovery from waste. The directive came into full force by 16 August 2009. (European Commission , 1999)

- Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the incineration of waste (WID)

  The directive deals with the incineration or co – incineration of waste in the EU. It imposes strict regulations on the emission limits of the pollutants being released in the air or water after incineration of the waste. It also mentions the operating conditions and technical requirements of a waste incineration plant. This directive was majorly effective in reducing the pollution from the waste incineration plants and pushing the market for a more

sustainable and clean energy recovery from waste scenario in the EU. (European Commission, 2000)

- Regulation (EC) No 2150/2002 of the European Parliament and of the Council of 25 November 2002 on waste statistics

  This regulation is responsible for creating and maintaining waste management statistics at the EU level. This helps the EU with regular monitoring of the generation, recovery and disposal of waste across its member states. (European Commission, 2002)

- Regulation (EC) No 1013/2006 of the European Parliament and of the Council of 14 June 2006 on shipments of waste

  The regulation aimed at simplifying the shipment of waste between member states. It laid down specific procedures in order to improve environmental protection. It monitors the movement of waste between the member states. The regulation specifies the documentation that is needed to reported and also the security measures required during transportation. The regulation considers every kind of waste except radioactive waste and is based on the International Basel Convention. (European Commission, 2006)

- Directive 2008/98/EC of the European Parliament and of the council of 19 November 2008 on waste and repealing certain directives:

  The directive sets up a legal framework for the treatment of waste in the European Union. It also defines many terms used in the waste management area like 'waste', 'hazardous waste', 'waste management', 'recycling', 'disposal' to name a few. The directive is also responsible for introducing to the concept of waste hierarchy and polluters pay price in the EU along with various legislations related to waste management. It is a very important directive which lays the groundwork for upcoming directives in the EU regarding waste. The directive came into force from 12$^{th}$ December 2010. (European Commission, 2008)

  *Focus on the End of Waste status*

  The sixth article in the directive discusses the product status of waste. It simply means whether the waste that is being used has reached its final stage to be called a waste or if it can achieve a product status, in which case different regulations would be applied. The aim is to promote recyclability. According to the directive, the criteria required to achieve product status are (Alejandro Villanueva, 2010):

  - "The substance or object is commonly used for specific purposes a market or demand exists for such a substance or object;
  - The substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products;
  - The use of the substance or object will not lead to overall adverse environmental or human health impacts."

*Definitions of waste treatment operations*

In the Waste Framework Directive (2008/98/EC) basic waste treatment operations are defined as follows:

**Recycling**
Recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original purpose or for any other purpose, including the reprocessing of organic waste and excluding energy recovery and the reprocessing into materials that are to be used as a fuel or as a filling material. These are the general recycling end use nomenclature that is used (European Commission, 2008):

- R3: Recycling of organic substances that are not used as solvents.
- R4: Recycling of metals and metallic compounds.
- R5: Recycling of inorganic material.

**Reuse**
Any act by which products or components that are not waste, again are used for the same purpose for which they were intended.

**Recovery**
Any operation the principal result that waste serve a useful purpose by replacing materials that would otherwise be used for a specific function, or by which the waste is prepared for a function. The included actions that are part of this are listed in Annex II to the Waste Framework Directive (2008/98/EC). The general recovery nomenclature are as follows (European Commission, 2008):

- R1: Use of waste principally as a fuel or other means to generate energy.
- R2: Solvent reclamation/regeneration
- R6: Regeneration of acids or bases
- R7: Recovery of components used for pollution abatement.
- R8: Recovery of components from catalysts.
- R9: Oil re-refining or other reuses of oil
- R10: Land treatment resulting in benefit to agriculture or ecological improvement
- R11: Use of wastes obtained from any of the operations numbered R1 to R10
- R12: Exchange of wastes for submission to any of the operations numbered R1 to R11
- R13: Storage of wastes pending any of the operations numbered R1 to R12 (excluding temporary storage, pending collection, on the site where it is produced)

**Disposal**
According to the WFD, disposal is any operation whose ultimate aim is not recovery even though there can be a reclamation of substances or energy. The nomenclature generally used for disposal is as follows (European Commission, 2008):

- D1: Deposit into or onto land, e.g. landfill
- D2: Land treatment, e.g. biodegradation of liquid or sludgy discards in soils

- D3: Deep injection, e.g. injection of pumpable discards into wells, salt domes or naturally occurring repositories
- D4: Surface impoundment, e.g. placement of liquid or sludgy discards into pits, ponds or lagoons
- D5: Specially engineered landfill, e.g. placement into lined discrete cells which are capped and isolated from one another and the environment
- D6: Release into a water body, except seas/oceans
- D7: Release into seas/oceans, including sea-bed insertion
- D8: Biological treatment resulting in final compounds or mixtures which are discarded by any of the operations numbered D1 to D12
- D9: Physico-chemical treatment resulting in final compounds or mixtures which are discarded by any of the operations numbered D1 to D12, e.g. evaporation, drying, calcination
- D10: Incineration on land
- D11: Incineration at sea
- D12: Permanent storage, e.g. emplacement of containers in a mine
- D13: Blending or mixing prior to submission to any of the operations numbered D1 to D12
- D14: Repackaging prior to submission to any of the operations numbered D1 to D13
- D15: Storage pending any of the operations numbered D1 to D14 (excluding temporary storage, pending collection, on the site where it is produced)

- EU Timber Regulation (EUTR – Regulation (EU) No 995/2010

  All timber and wood products are subjected to this regulation so as to avoid any illegal trans-shipment of timber in the EU. Only waste is exempt from this regulation. Waste wood or post-consumer wood waste is a material that has completed its life cycle or would have been otherwise be discarded. Primary and secondary wood residues do not fall under the waste category and have to transported under the EUTR Regulation. Although, post-consumer wood waste does not fall under the regulation. (European Commission, 2010)

- Basel Convention

  The Basel Convention was introduced to control the trans boundary shipment of hazardous waste and their disposal. It was introduced on 22$^{nd}$ March 1989 after a public outcry by Africa in the 1980's, after it was found out that many developed nations were disposing their hazardous waste in Africa. The convention major aim is to promote better health and living conditions of people around the world against the ill effects of hazardous waste. The convention entered into full force by 1992. (UNEP, 1992) The convention covers a varied list of hazardous waste, based on their composition, origin and characteristics.

  The convention focuses on these principal goals (UNEP, 1992):

  1. Reducing the hazardous waste generation and promoting the sustainable management of hazardous waste.
  2. Restricting the trans boundary shipment of hazardous waste to countries where it is illegal to dispose and ensuring the movement is to countries that have environmentally sound waste management systems.
  3. A regulatory system for the countries that can deal with hazardous waste.

The EU has ratified and adopted the Basel Convention whereas US has only adopted the convention, but not ratified it yet. The regulation applies to:

- Within the EU member states.
- Imported to the EU from Third World countries.
- Exported from the EU to Third World countries.
- In transit

The transported waste is classified into two further categories, one of the hazardous nature are part of the 'Amber list' and one of the non-hazardous nature are generally part of 'Green list'. But even though, a green listed waste is transported for energy recovery purpose in any member state of EU, it has to be notified.

## 3.6. NATIONAL LEGISLATIONS

### 3.6.1. THE NETHERLANDS

The Netherlands has been actively involved in the waste management in their country. It came up with a National Waste Management Plan (NMWP) for 2009 – 2021 which provides a great deal of insight on different types of wastes, their definitions, the import and export laws and the end use of the waste. The NWMP has individual chapters for different kinds of waste with Section 36 for wood. Section 36 discusses wood waste in detail. The wood waste is divided in three types (Rijkswaterstaat Environment, 2009):

- A – type wood waste: Clean wood waste with no paint or hazardous substance.
- B – type wood waste: Wood waste that does not fall under A or C – type. This has a bit of paint or glue which can be easily cleaned.
- C – type wood waste: wood waste with hazardous substance impregnated in the wood or if the wood is treated for extending the lifetime of the product.

The NWMP also suggests the end use of each type of wood waste. For A and B type, the wood waste should be recovered, either by recycling or by creating energy out of it. For C – wood, there are two options. Either, it can be disposed off in a suitable landfill or the impregnated wood must be pretreated appropriately, taxes are paid and the residues are taken care of so that it does not mix with the environment.

The shipments to the Netherlands with treated wood waste are prohibited under national self-sufficiency, if it is purposed for disposal in landfills. The shipments of treated wood are only allowed if there is permission to incinerate according to Dutch minimum standards. (Rijkswaterstaat Environment, 2009) The transport of waste is subjected to very specific rules and regulations in the Netherlands. It strictly follows the EU Waste Framework Directives and regulations. The major problem is to identify whether the product is waste or not, and it is determined by the province or the municipality, case by case. In either case, whether the product is waste or not, the energy plants must have appropriate license to utilize it for energy recovery (NL Agency, NL Energy and Climate Change, 2013).

### 3.6.2. GERMANY

**European Laws**

Waste management and disposal has always been a point of interest in the EU and hence a lot of regulations and directives are already established. Germany, being a member state follows all the directives and regulations. The basis of its waste policies is the waste framework directive.

**German Federal Law**

Germany launched its first nationwide waste disposal act, the Abfallbeseitigungsgesetz (AbfG) in 1972. Since then, it has implemented and introduced many new policies to achieve a healthier and more sustainable environment. Germany has a new waste disposal law called the Circular Economy Act which takes its roots from the AbfG act. The aim of this act is to promote circular economy in Germany and conserve the natural resources. It came into force on 1st June 2012. The Circular Economy Act (KrWG) is intended to strengthen resource, climate and environmental protection regulations. (Bundesgesetzblatt, 1972)

**State law of Bundesländer**

The Circular Economy Act is applied further in different regions (bundesländer) of Germany and is known as Circular Economy Act of the Bundesländer. Since, the federal government is responsible for implementing the EU level regulations and laws, the state government is only responsible for smaller laws regarding the regions. The major task is to determine which commodities are subjected to waste disposal obligations, establish authorizing bodies for waste disposal issues and MSW ordinances.

Apart from the European, federal and state laws, there are various ordinances which helped the cause of recovered wood in Germany. The most important ordinances regarding recovered wood are: The Circular Economy Act, the ordinance on incineration plants, the ordinance on the management of waste wood, the act on granting priority to renewable energy sources, The ordinance on generation of electricity from Biomass and the ordinance of harmonized waste list.

**German Ordinance on Incineration Plants**

The German ordinance on incineration plants majorly focuses on the emission limits of the pollutants from the incineration plants. It was first proposed on 23rd November 1990. It was amended again on 14th August 2003, because it had to align its national laws to the European directive of waste incineration plants, 2000/76/EC released on 4th December 2000. It lists the different solid and liquid fuels used for the incineration plants apart from regular fuels and also places stringent rules and regulations, in case the fuel is hazardous in nature. In case of co – incineration plants using wood waste, rules and regulations applied are based on the fraction of wood waste being used and the emission limits changes accordingly. (BMUB, 1990)

**Ordinance on the Management of Waste Wood - (Altholzverordnung - AltholzV)**
The Circular Economy Act was a great step ahead in promoting a sustainable environment in Germany but the scope was vast at the same time. A separate ordinance regarding management of waste and recovered wood guarantees a better standard for waste wood in the country. This will lead to a healthier competition in the market, creating new and exciting opportunities and better material and energy recovery. The ordinance came into full force from 1st March 2003. This ordinance was a trial ordinance for different material specific ordinances in Germany. The reasons to choose waste wood are (BMUB, 2003):

- It's a significant volume flow for energy and material recovery.
- The recovery options of waste wood in Germany were of questionable standards.
- There was a need of a common nationwide rule regarding waste wood in Germany.

The ordinance identifies all the used methods for waste wood management. There are only two recovery paths identified in the ordinance: Energy recovery or recycling. Landfilling of waste wood is not permitted and must be incinerated if nothing else is possible.

Waste Wood Categories
Waste wood must be assigned to one of four of the following waste wood categories depending on the level of pollution.

- Waste wood category A I: Waste wood in its natural state with no contamination to wood.
- Waste wood category A II: Painted, lacquered or otherwise treated without any halogenated organic chemicals and no wood preservatives.
- Waste wood category A III: Waste wood with halogenated chemicals but no preservatives.
- Waste wood category A IV: Waste wood impregnated with wood preservatives.

A lot of different ways exists in which the wood can be recycled or re – used. The different recycling or re – use methods of the wood waste are discussed in the table below with the following considerations that must be considered:

Table 3: Recovery Methods of Waste Wood Categories (Source: *(Peek, 2004)*)

| **Recovery Method** | **Permissible waste wood categories** | | | | **Special Requirements** |
|---|---|---|---|---|---|
| | A I | A II | A III | A IV | |
| **Processing of waste wood to wood chips for secondary timber products** | Yes | Yes | Yes* | - | The processing of A III is only permissible if the wood has gone through pre-treatment process and wood varnish and coatings have been removed. |
| **Production of synthetic gas for chemical use** | Yes | Yes | Yes | Yes | Recycling is only permitted in installations that have proper licensing. |
| **Manufacture of active carbon/industrial charcoal** | Yes | Yes | Yes | Yes | Recycling is only permitted in installations that have proper licensing. |

For energy recovery purposes, priority is given to those type of wood wastes which cannot be re used to produce derived secondary timber products. Generally, wood waste with preservatives or treatment are used for energy recovery. The energy recovery for hazardous wood waste is highly regulated.

Currently, the A I waste wood can be processed in furnace with thermal output of <50 kW. Group A II are allowed in furnaces with thermal output of 50 kW to 1 MW. Furnaces which can control the emissions of harmful substances can use group A I, A II and A III. For A IV, the highest requirements of seventeenth ordinance of federal emission control act is required.

**Other regulations**

Apart from the KrWG, there are various regulations in Germany, such as the Abfallverzeichnis-Verordnung (AVV) regulation which is responsible for classification of waste into hazardous and non-hazardous waste. It aims at monitoring the type of waste that is present in Germany.

*German Act of Granting Priority to Renewable Energy Sources*
The act was a successor to the Electricity Feed Act. The act was a decisive breakthrough in providing support to sustainable energy systems in Germany. the Renewable Energy Sources Act (Erneuerbare-EnergienGesetz;EEG) regulates the prioritization of grid supplied electricity from renewable sources. It specifies mechanisms for implementing the option of granting priority to renewable power generation envisaged in the EU Directive on the internal market in electricity. Energy utilities also benefit from the compensation for supplying the grid with electricity from renewable sources. (Erneuerbare-EnergienGesetz;EEG, 2000)

The act guaranteed compensatory payment down to the last kWh making a secure environment for investing in renewable energy. The section 5 of the act talks more about the compensation provided for the electricity produced from biomass. According to the act, it states the following compensation:

1. “At least 10.23 cent per kilowatt-hour in the case of installations with an installed electrical capacity of up to 500 kilowatts.
2. At least 9.21 cent per kilowatt-hour in the case of installations with an installed electrical capacity of up to 5 megawatts.
3. At least 8.70 cent per kilowatt-hour in the case of installations with an installed effective electrical capacity of over 5 megawatts; however, this provision shall not be effective before the date of the entry into force of the ordinance specified in the second sentence of Section 2”

### 3.6.3. SWEDEN

**European Laws**
Sweden is also a member state of the EU. Therefore, it must follow all the directives and regulations already discussed in the Waste Framework Directive.

**The Environmental Code of Sweden**

The purpose of the Environmental Code is to promote sustainable development which will ensure a healthy and sound environment for present and future generations. To achieve this, the code is to be applied so that (Ministry of Environment, Sweden, 1999):

- Human health and the environment are protected against damage and detriment, whether caused by pollutants or other impacts
- Valuable natural and cultural environments are protected and preserved
- Biodiversity is preserved
- The use of land, water and the physical environment in general is such as to secure long-term good management in ecological, social, cultural and economic terms
- Re-use and recycling, as well as other management of materials, raw materials and energy are encouraged so that natural cycles are established and maintained.

**Waste ordinance**

The waste ordinance was released on 1st January 2002. Two major ordinances, Waste collection and disposal (1998:902) and Hazardous Waste Ordinance (1996:971) were merged to form the Waste Ordinance. This was designed to simplify the waste laws and legislation in Sweden and to implement the EU Waste List. The permit procedures for hazardous waste were simplified in this ordinance and double permits were removed because the ordinances were merged into one.

**Ordinance on Landfilling of Waste**

Since 2002, it has been prohibited by the Ordinance on Landfilling of Waste to dispose off unsorted combustible waste at a landfill site. In 2005, the ban was extended to cover all organic waste with certain exceptions. Sweden also introduced a landfill tax to further prohibit the disposal of waste in landfills. (SEPA, 2004)

### 3.6.4. UNITED KINGDOM

**European Laws**
The United Kingdom is a member state of the EU. Therefore, it must follow all the directives and regulations already discussed in the Waste Framework Directive.

**National Laws, Policies and Legislations:**

The legislations and policies regarding waste differs a lot in the UK than the rest of the Europe. Waste wood has different definitions and hence the policies applied also vary according to the definitions. The wood waste is divided into 4 grades as follows:

Table 4: Grades of Wood Waste in the United Kingdom (Source: (WRAP, 2011))

| GRADE | SOURCE OF RAW MATERIAL | CONSTITUENTS |
|---|---|---|
| **Grade A – Clean Recycled Wood Waste** | Distribution, Packaging, Retail, Secondary Manufacturing | Solid softwood and hardwood.<br>Packaging waste, scrap pallets, packing cases, and cable drums.<br>Process off-cuts from manufacture of untreated products. |
| **Grade B – Industrial Feedstock** | Grade A but with construction and demolition waste | Contains approximately 60% of Grade A waste with wood waste from construction and demolition sector. |
| **Grade C – Fuel Grade** | Grade A and B with Municipal and Civic waste | All of the above plus fencing products, flat pack furniture made from board products and DIY materials<br>High content of panel products such as chipboard, MDF, plywood, OSB and fiberboard. |
| **Grade D – Hazardous Waste** | All of the above plus the fencing, track work and transmission poles. | Fencing<br>Transmission Poles<br>Railway sleepers<br>Cooling towers |

Landfilling Bans

In 2011, the review of waste policy in England announced the Government's intention to consult on the ban on landfilling of wood waste in 2012. The board invited suggestions from academicians and experts from all over the country and it received 37 written suggestions. It decided on the basis of all the suggestion to not go forward with the ban on landfilling of wood waste, which has affected the wood waste market in the UK.

The landfilling tax was seen as a key driver to divert the wood waste from landfilling to proper recycling and recovery. There were many benefits of the landfilling bans such as improved recycling infrastructure, innovation in the wood waste recovery sector, better producer responsibility and moving wood waste up in the waste hierarchy. But the restriction was denied based on the reasons below (Department for Environment, Food And Rural Affairs, 2013):

- Lack of collecting and sorting infrastructure.
- Proper identification of wood waste treatments and its effect on the end markets.
- Enforcement of the legal restriction on a nationwide level.
- Lack of storage capacity and segregation space.
- Sudden increase in the costs.

Export and Import of Wood Waste

The trans boundary shipment of wood waste in the United Kingdom is based on the EU Waste Shipment Regulations (1013/2006). Under this regulation, the waste can be shipped under three categories:

- Green List: The waste that has the minimum effect on the environment fall under this list. These are mostly recyclable waste and can be transported without any prior permissions.
- Recovery: The waste that can be recovered has to be notified to the proper authorities prior to the shipment.
- Disposal: The export for disposal of waste is not permitted in the UK but only under extreme circumstances.

Waste wood does not fall under the ambit of green list waste and hence it can only be exported if it can be recovered. The waste wood requires minimal environmental permits by the environmental agency, since the waste wood is regarded as 'low waste risk' activity. (Tolvik Consulting, 2011)

# 4. RESULTS

## 4.1. THE NETHERLANDS

### 4.1.1. Trends in Import and Export of Waste Wood

The Netherlands deals with a considerable amount of wood waste in Europe and is a major exporter as well as importer of both hazardous as well as non-hazardous wood waste. The Netherlands has 4 major bioenergy plants that run on waste wood which import non-hazardous waste wood for the feedstock of their plants namely Bioenergie Centrale (Delfzijl), Twence, HVC Groep and AVR Afvalverwerking. In 2015, the bioenergy plants imported around 260 KT of wood waste for maintaining their feedstock. The wood waste imported for bioenergy plants is majorly B – Type wood waste which corresponds to the 191207 on the EWC list. The three major exporters of wood waste to The Netherlands are the United Kingdom, Belgium and Germany. The United Kingdom is the primary exporter of wood waste for energy recovery purposes in the Netherlands. The Netherlands had a sudden increase of wood waste from the end of 2012, when majority of its bioenergy plants were established including Eneco, which is the largest wood waste bioenergy plant in the Netherlands. According to the information collected through various interviews from waste stakeholders, Eneco used to import 80,000 tons from the United Kingdom itself for maintaining a consistent supply of its wood waste but the supply has been constantly decreasing ever since the UK has decided to use the wood waste for energy recovery in their country.

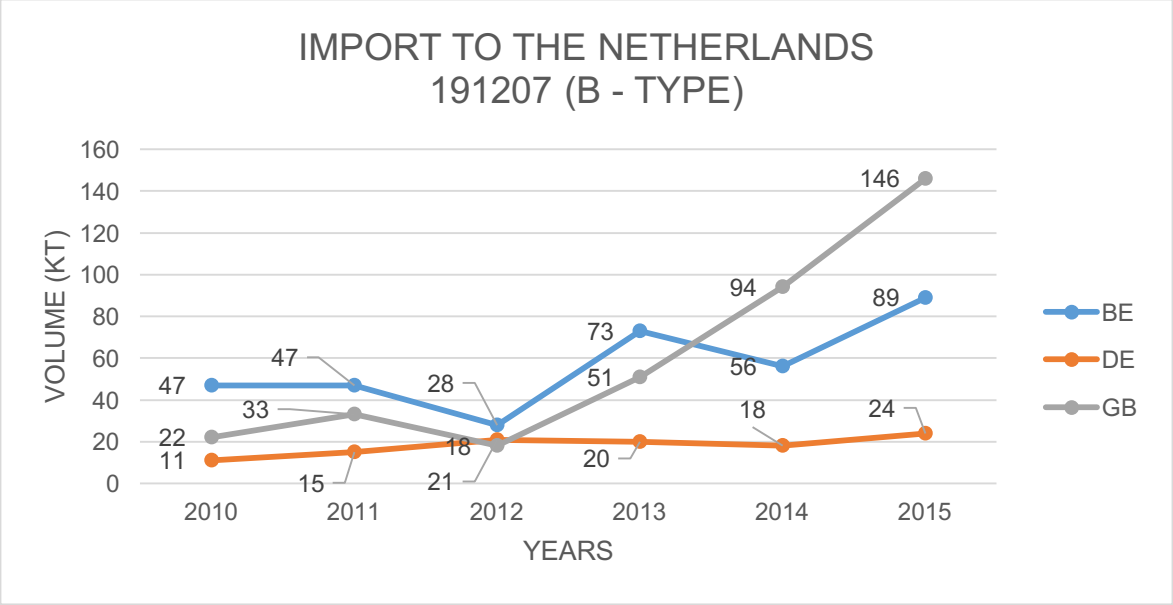


Figure 4: Import to The Netherlands 191207

The Netherlands also exported the B type wood waste to Germany and Belgium in large quantities in the years 2010 - 2015. Germany had a steady bioenergy market which was already established due to the renewable energy friendly policies. In Belgium, the demand for wood waste is majorly for material recovery in the chipboard industry. (NL Agency, NL Energy and Climate Change, 2013)

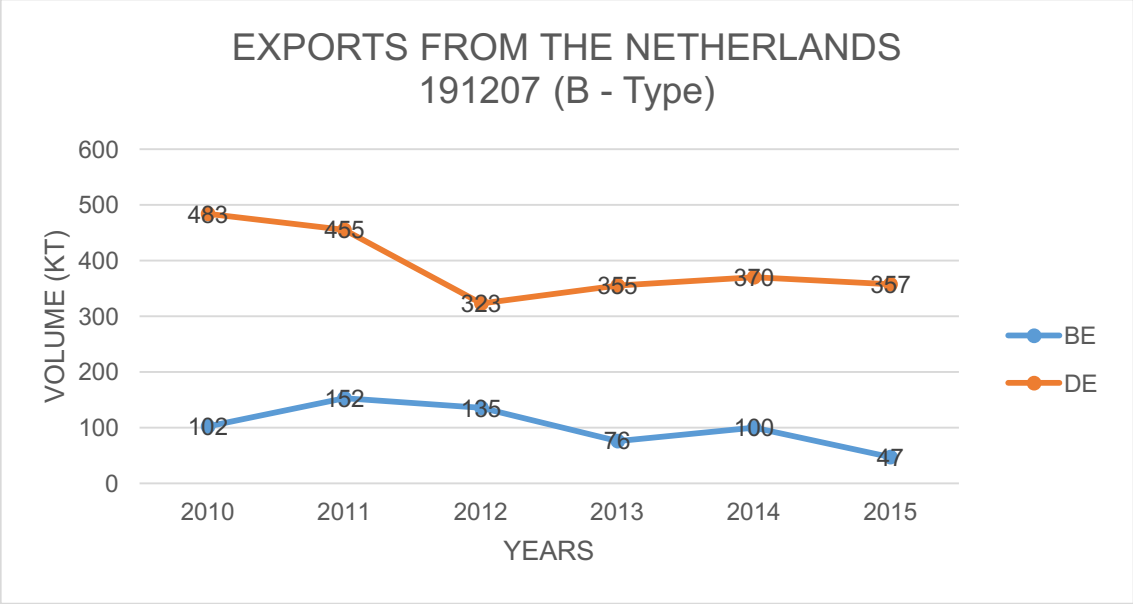


Figure 5: Export from The Netherlands 191207

The Netherlands produces hazardous wood waste on a large scale and most of it is exported to other countries. The major importer of C type wood waste or 191206* according to the EWC list, from The Netherlands is to Germany. The exported volume is used majorly for energy recovery. It has consistently exported 100+ KT to Germany for its wood waste based bioenergy plants. It is costly in the Netherlands to incinerate the hazardous wood waste for energy recovery purposes, hence it is majorly exported to Germany. (Mark van Benthem, 2005) Also, there is no provision in the legislation of the Netherlands to take care of hazardous wood waste by landfilling. Landfilling of hazardous wood waste is illegal and hence it is shipped to Germany. (VROM, The Netherlands, 2004)

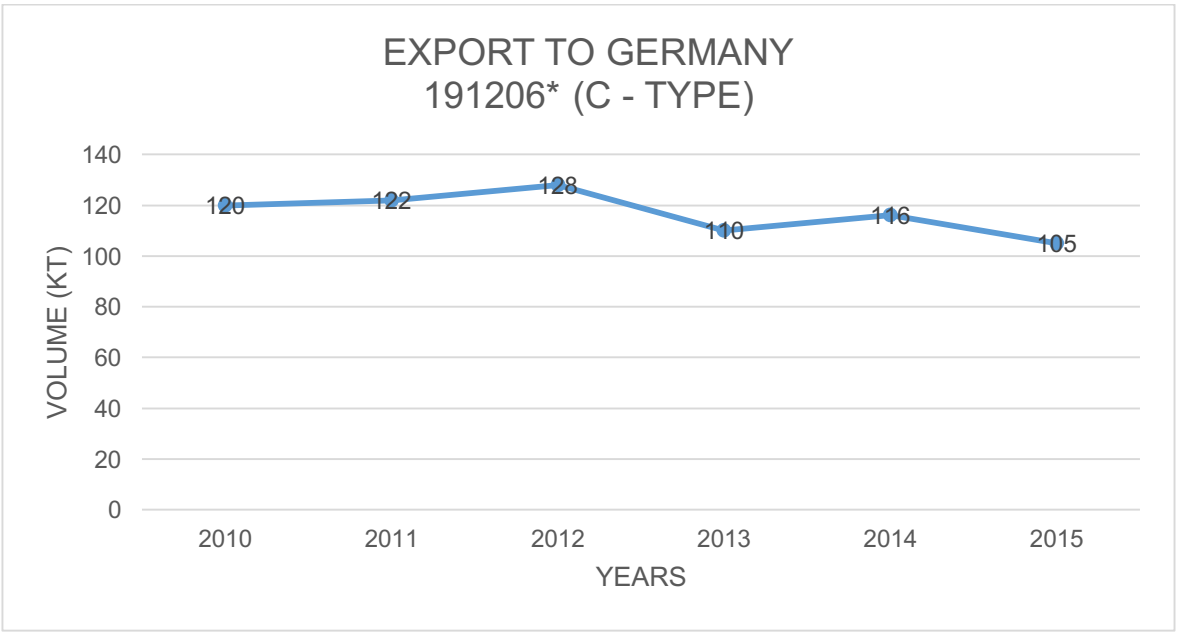


Figure 6: Export from Netherlands to Germany 191206*

### 4.1.2. Share in Primary Energy Supply

According to the IEA Energy Statistics, the Netherlands had a primary energy supply of 3.05 EJ in 2014 from every energy source. Out of the 3.05 EJ, bioenergy and waste supplied around 0.15 EJ, roughly around 5% of total primary energy supply. This gives an insight that the Netherlands is a country which has a prominent share of bioenergy in their energy system. The primary energy supply of only bioenergy is 81 PJ. The wood waste being used for the energy recovery purpose has a calorific value of 14 MJ/kg. The amount of wood waste imported in 2014 is 168 KT. The primary energy supplied from the imported wood waste is 2.35 PJ which is 2.9% of the bioenergy share.

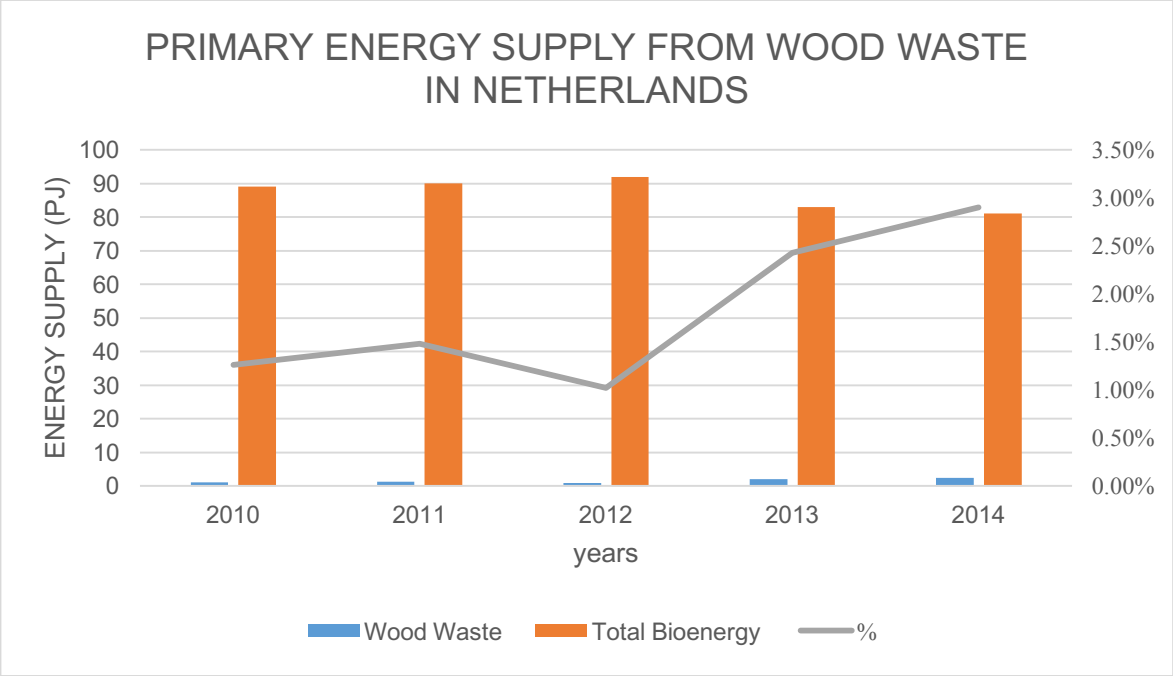


Figure 7: Primary Energy Supply from wood waste and share in total bioenergy

The end use of wood waste with EWC 191207 is energy recovery in the various energy industries setup on the basis of wood waste. The hazardous wood waste can end up in landfill after proper treatment, hence it is mainly exported to Germany where it is used for energy recovery purposes. The export to Belgium is majorly for its particle and chipboard industry.

## 4.2. GERMANY

### 4.2.1. Trends in import and export of wood waste

Germany is the net importer of waste wood in the EU. It imports the maximum amount of wood waste which rounded off to 780 KT, both hazardous and non-hazardous.

Germany is a net importer of B type wood waste or 191207 from the EWC list. The major exporters to Germany are the Netherlands and Switzerland. As seen in the section above, the Netherlands supplies a huge volume of B Type wood waste to Germany for a constant input of feedstock for all the bioenergy plants. Even though, it used to supply 480 KT in 2010, it is constantly decreasing due to various reasons. The sudden dip in imports from the Netherlands in 2012 is because of the increase of bioenergy plants that use wood waste as feedstock in the Netherlands. The Netherlands used the wood waste to produce energy in its own country rather than shipping it to Germany.

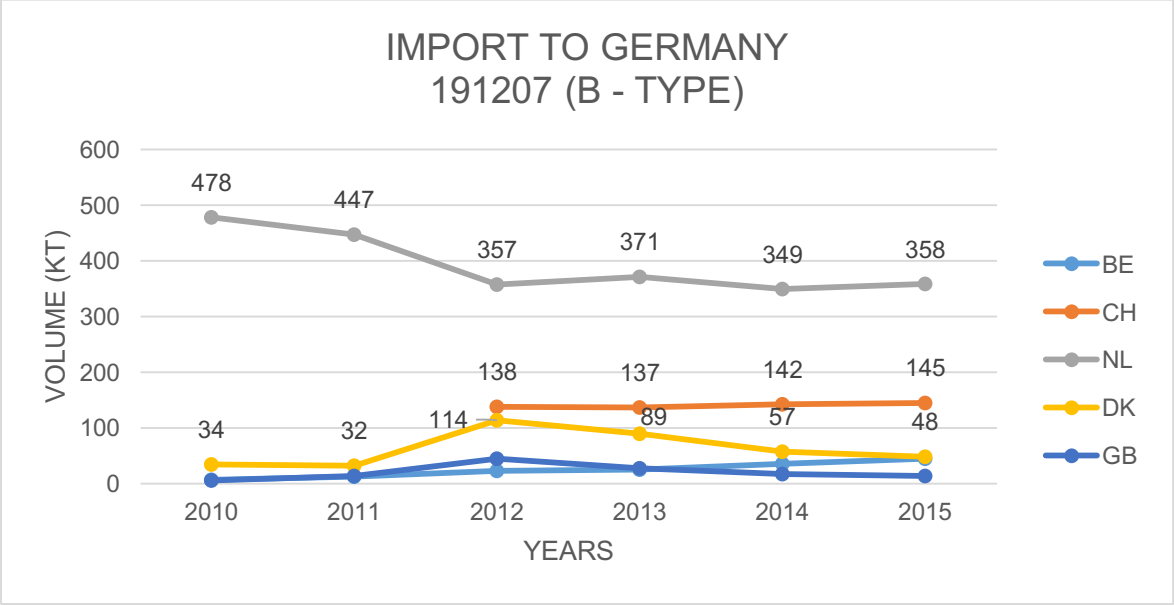


Figure 8: Import to Germany 191207

The C – type wood waste is imported from all over Europe, majorly from the Netherlands (100+KT/yr) and Denmark (50 KT/yr). Finland, Switzerland and Austria have a consistent supply of 20 KT. It has the capacity as well as proper legislations and policies to support the energy recovery process of hazardous waste wood which are discussed in detail in further sections. Hence, it is a net importer in Europe during the years 2010-2015.

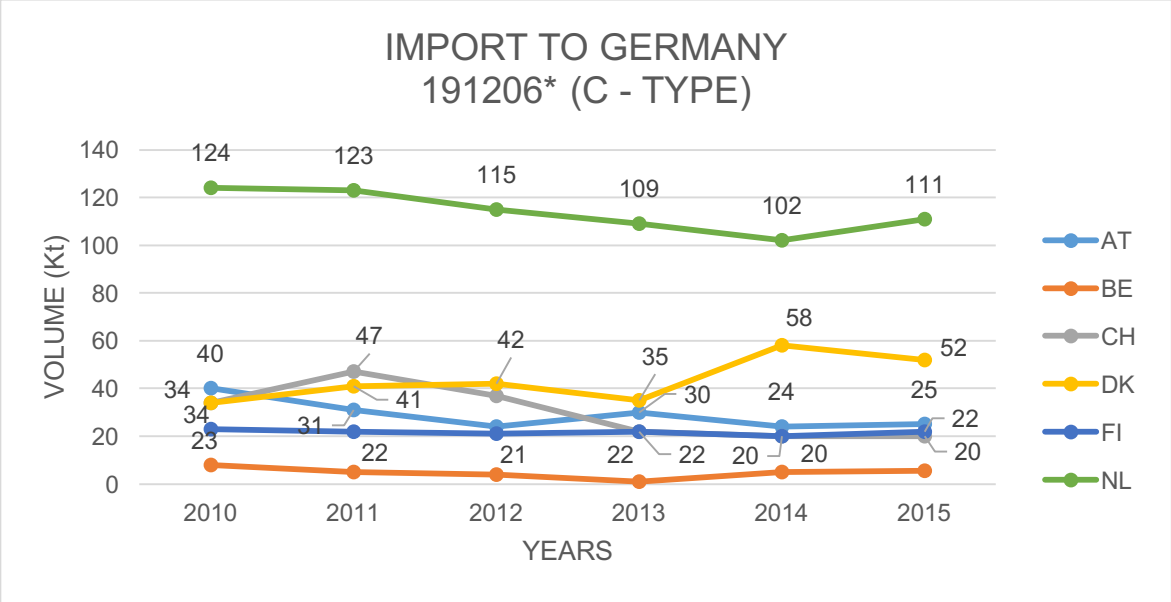


Figure 9: Import to Germany 191206*

### 4.2.2. Share in Primary Energy Supply

According to the IEA Energy Statistics, Germany had a primary energy supply of 12 EJ in 2014 from every energy source. Out of the 12 EJ, bioenergy and waste supplied 1.22 EJ, which is roughly around 10% of total primary energy supply. Due to the renewable energy, friendly legislation such as the renewable energy sources act reflects in the 10% share of biomass in Germany's primary energy supply. The primary energy supply of only bioenergy is 945 PJ. The wood waste being used for the energy recovery purpose has a calorific value of 14 MJ/kg. The amount of wood waste imported in 2014 is 829 KT. The primary energy supplied from the imported wood waste is 11.61 PJ which is 1.23% of the bioenergy share.

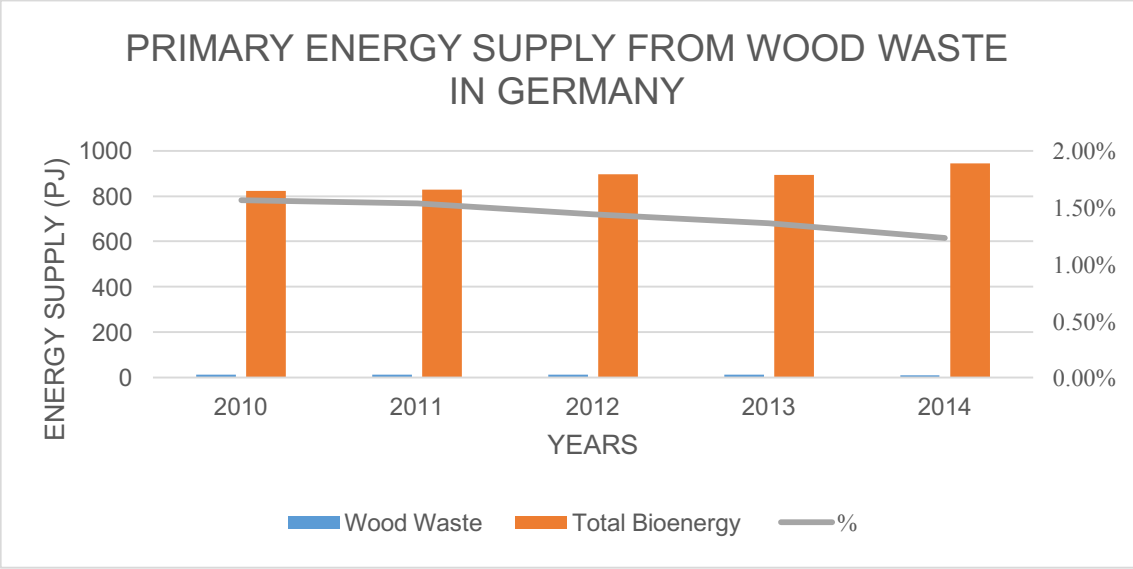


Figure 10: Primary energy supply from wood waste and share in total bioenergy

The end use in Germany is majorly energy recovery both for hazardous as well as non-hazardous wood waste. As mentioned earlier, Germany has 700 bioenergy plants and require a constant feedstock for energy production.

## 4.3. SWEDEN

### 4.3.1. Trends in Import and Export of Waste Wood

Sweden is another net importer of waste wood in the EU. It imports the second highest amount of wood waste in the EU around 681 KT, both hazardous and non-hazardous waste.

Sweden is a net importer of B type wood waste. The major exporters to Sweden are United Kingdom and Norway. Sweden highly depends on the wood waste supply from United Kingdom and Norway for maintaining a constant supply of feedstock for its CHP plants. Even though, UK supplied 300+ KT during 2010 - 2014, it is constantly decreasing due to various reasons. The supply of wood waste from the UK highly depends upon the price of wood waste. Also, since 2015, UK has started new bioenergy plants whose feedstock is wood waste, hence the reduction in exports is explainable.

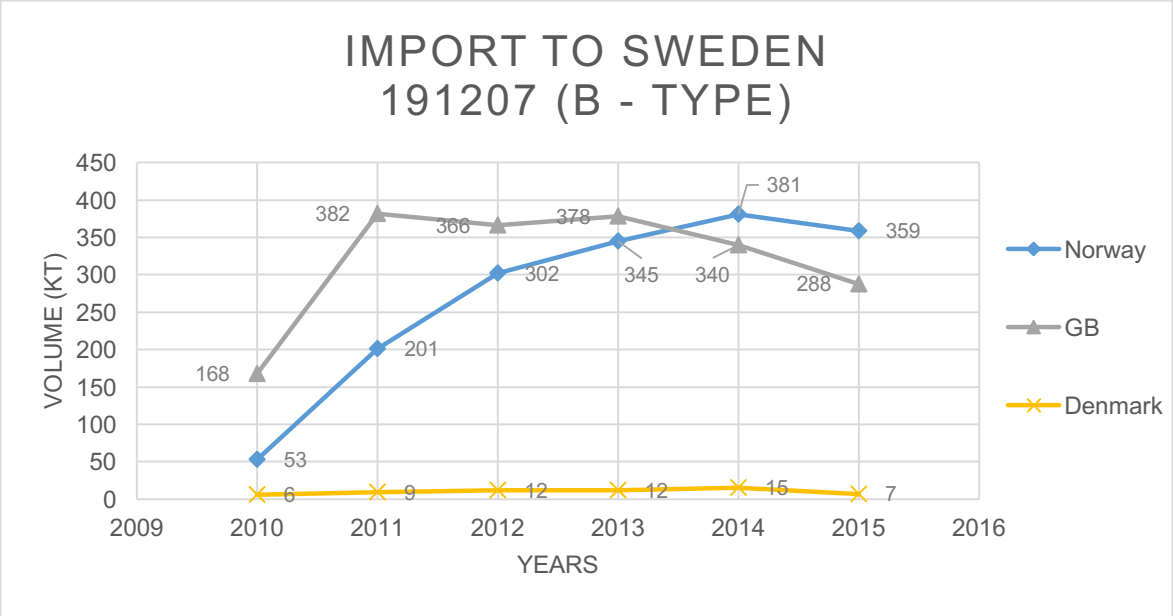


Figure 11: Import to Sweden 191207

The C – type wood waste is imported majorly from Norway depending upon the generation of hazardous wood waste. Norway lacks the facilities to dispose off the hazardous waste. But Sweden has the capacity as well as proper legislations and policies to support the energy recovery process of hazardous waste wood and hence it is a net importer in Europe during 2010-2015.

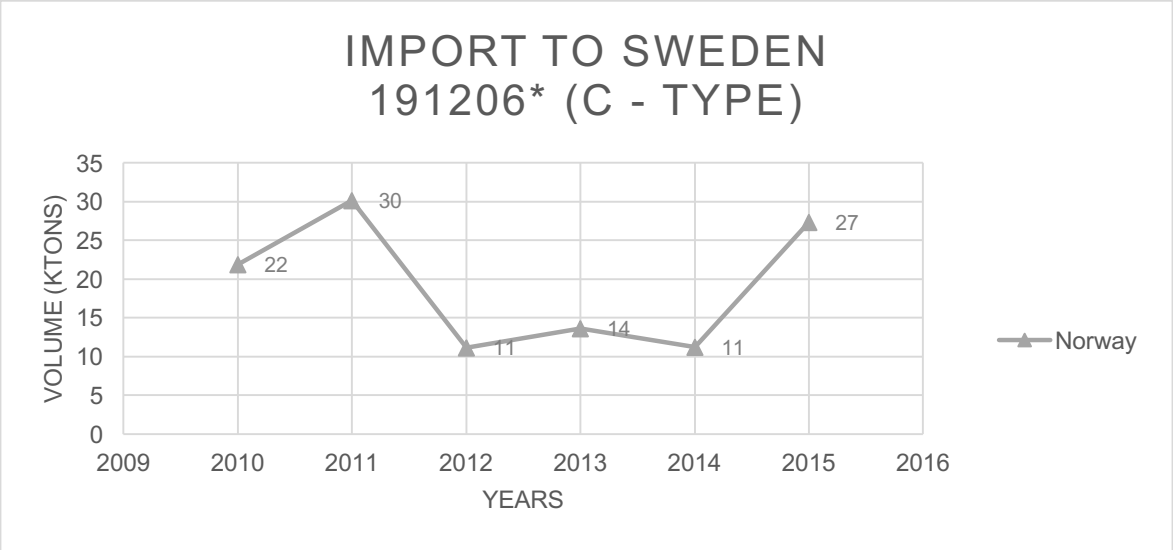


Figure 12: Import to Sweden 191206*

### 4.3.2. Share in Primary Energy Supply

According to the IEA Energy Statistics, Germany had a primary energy supply of 2.1 EJ in 2014 from every energy source. Out of the 2.1 EJ, bioenergy and waste supplied 0.48 EJ, which is roughly around 22.85% of total primary energy supply. This is majorly because of the large amounts of CHP plants all over Sweden providing energy all throughout the year. The primary energy supply of only bioenergy is 31.5 PJ. The wood waste being used for the energy recovery purpose has a calorific value of 14 MJ/kg. The amount of wood waste imported in 2014 is 747 KT. The primary energy supplied from the imported wood waste is 10.458 PJ which is 2.47% of the bioenergy share.

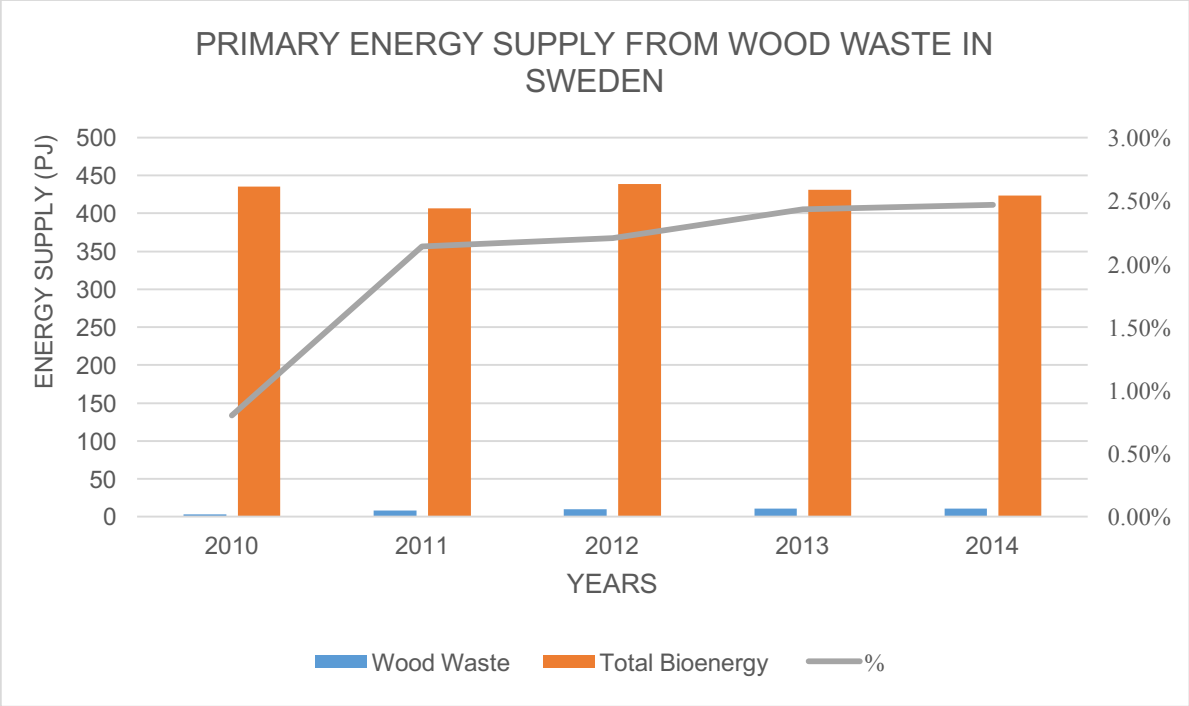


Figure 13: Primary Energy Supply from Wood Waste in Sweden and share in total bioenergy

The end use in Sweden is for energy recovery purposes in the CHP plants set up across the country. The CHP plants run on the feedstock of waste, such as MSW as well as Wood Waste and the imported wood waste is used for energy recovery purposes. The waste is rarely landfilled because of strict landfill laws and taxes.

## 4.4. UNITED KINGDOM

### 4.4.1. Trends in Import and Export of Waste Wood

United Kingdom is a net exporter of waste wood in the EU. It is one of the most prominent exporters of non-hazardous wood waste. The United Kingdom requires permission for trans-shipment of hazardous waste, which is costly for many traders and industries and hence majority of the hazardous waste is dumped in landfills. The total export of non-hazardous wood waste was approximately around 500 KT in 2015.

The B– type wood waste is exported majorly to the Netherlands and Sweden. Belgium and Germany also import wood waste from the United Kingdom but the quantities are not high enough (10-50 KT/yr).

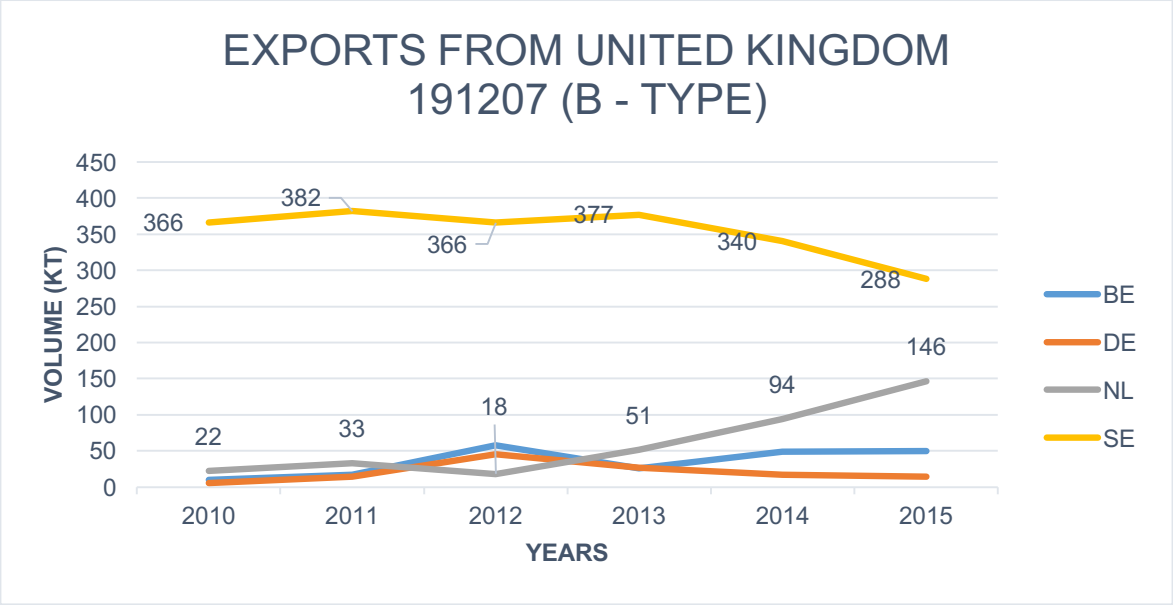


Figure 14: Exports from United Kingdom 191207

### 4.4.2. Share in Primary Energy Supply

According to the IEA Energy Statistics, United Kingdom had a primary energy supply of 7.5 EJ in 2014 from every energy source. Out of the 7.5 EJ, bioenergy and waste supplied 0.38 EJ, which is roughly around 5.1% of total primary energy supply. The primary energy supply of only bioenergy is 347 PJ. The wood waste being used for the energy recovery purpose has a calorific value of 14 MJ/kg. Since, the wood waste is being primarily being exported from the United Kingdom, the graph showcases the amount of primary energy it could have supplied to the country's energy share. The amount of wood waste exported in 2014 is 500 KT. The primary energy that could have been supplied from the exported wood waste is 7 PJ which is 2.02% of the bioenergy share.

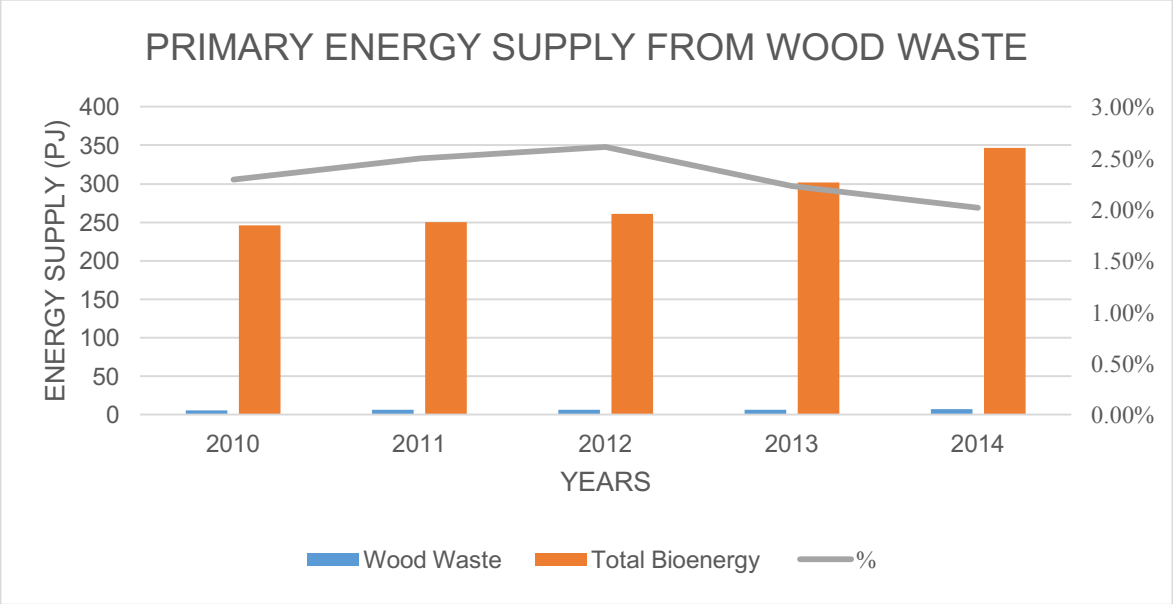


Figure 15: Primary Energy Supply from wood waste and share in total bioenergy

The end use of wood waste in UK is divided into a lot of sectors. Majority of the wood waste ends up in landfills as well as the panel board industry. Other recycling sectors include animal bedding and mulches. The remaining wood waste goes to wood waste to energy industries. (Anthesis, 2017)

## 4.5. EUROPE

### 4.5.1. NON HAZARDOUS WOOD WASTE (191207)

The B – Type Wood Waste also known as the non-hazardous wood waste is majorly imported by Germany and Sweden in Europe. The main countries involved in the trade are situated in the North Western part of Europe.

The total volume of B type wood waste transported in 2010 is 1190 KT. The B type wood is majorly used for R1 and R3 recovery paths since the EU regulations does not allow to ship the waste if it is being disposed off in a landfill. As seen in the figure, the major importer of wood waste in 2010 was Germany with a trade of 558 KT which is 47% of the imported wood waste in North Western Europe. The German laws and legislations made it easier for the biomass industry to set up successfully in the country. The increase in the biomass plants, required Germany to fulfil the feedstock requirements, and hence it imported most of the wood waste from neighboring countries, saving up on transportation costs too. Sweden is another major net importer of Northern Europe. It had major imports from Norway, UK and Denmark. One of the key drivers of high imports of wood waste to Sweden is the energy system infrastructure present in the country which made a sound environment for high energy recovery from waste. The early bans on landfilling in countries like Norway and the lack of energy recovery from waste technology led to high exports of waste from the country to Sweden.

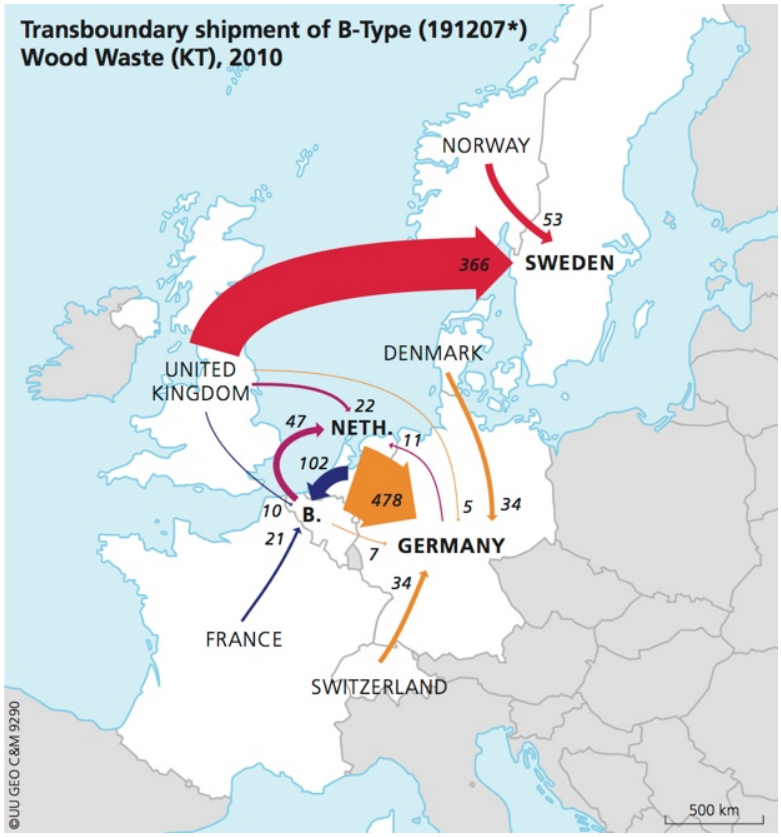


Figure 16: Transboundary shipment of B type Wood Waste, 2010

In 2011, the total shipment of B Type waste increased to 1384 KT in north western Europe. Sweden surpassed Germany becoming the top importer of wood waste standing at 592 KT which is 43% of the total shipment of wood waste in the area. Germany was the second largest importer with 505 KT of waste wood trade. Since, the capacity in the Netherlands was not high enough, it increased its export of wood waste to Belgium. Belgium used the wood waste majorly in chipboard industry. Norway increased the export to Sweden, since it applied taxation on waste incineration which drove the shipments to Sweden, where it was cheaper to use.

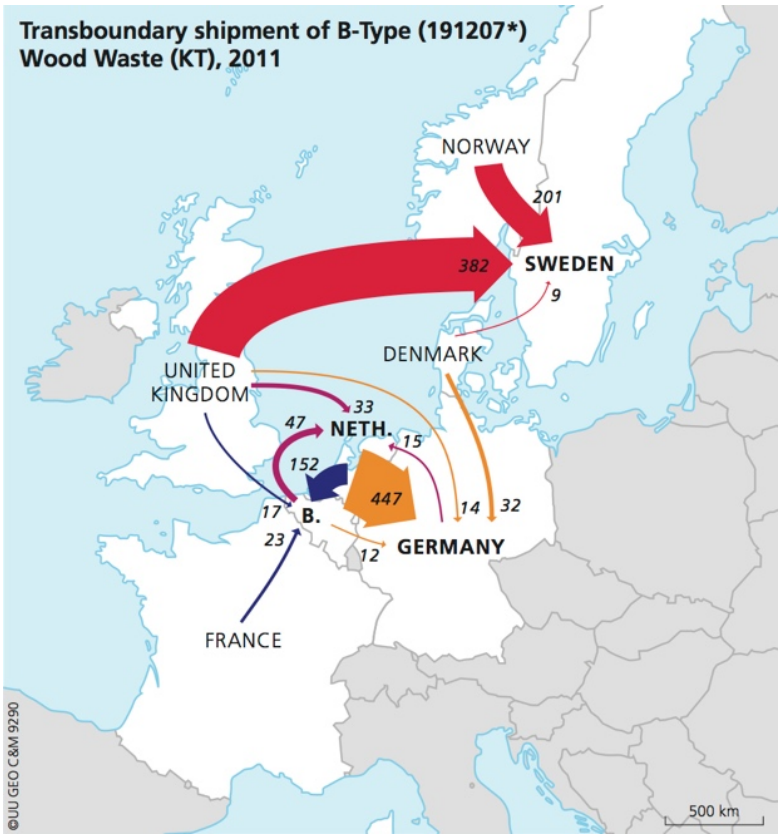


Figure 17 Transboundary shipment of B type Wood Waste, 2011

In 2012, the total shipment of wood waste increased to 1656 KT. Sweden and Germany both imported 690 KT of wood waste. The Netherlands had an interesting development with installation of the new Eneco wood waste fueled biomass plant, it reduced its export to Germany and Belgium. This lead to increase in exports from Denmark, UK and Switzerland to Germany for fulfilling the feedstock requirements of biomass plants.

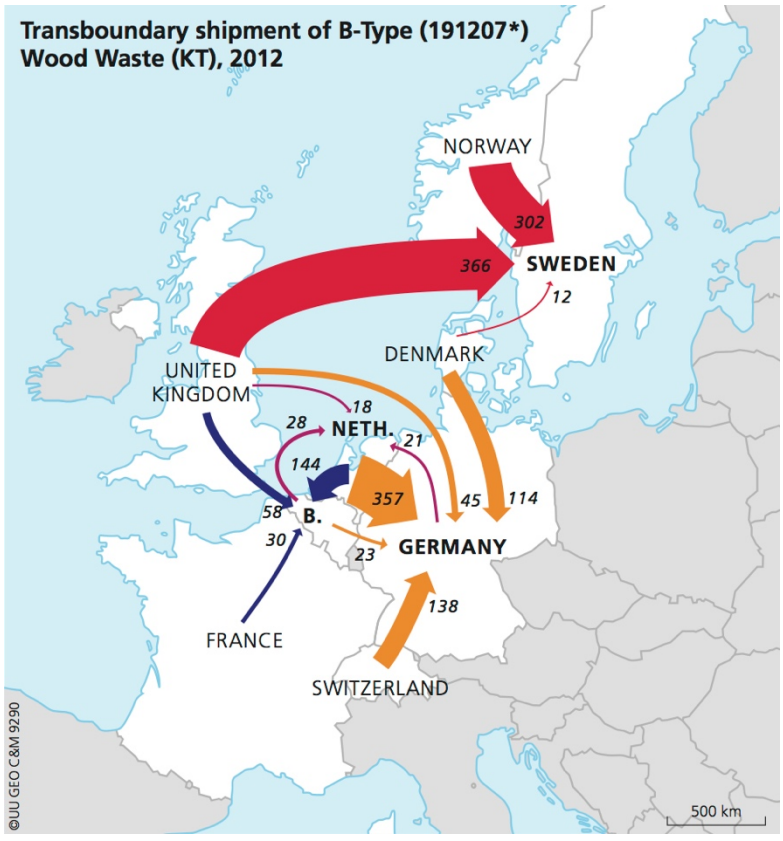


Figure 18 Transboundary shipment of B type Wood Waste, 2012

The net trade in 2013 increased to 1677 KT. The trend of Sweden and Germany being the top importers continued. Sweden imported 734 KT and Germany imported 649 KT of wood waste. The Netherlands also imported 144 KT of wood waste which is a 115% increase of imports due to new biomass plants running in the country. It became highly dependent on the imports from the UK, Belgium as well as Germany. It also reduced the exports to Belgium since the demand for wood waste increased in their own country.

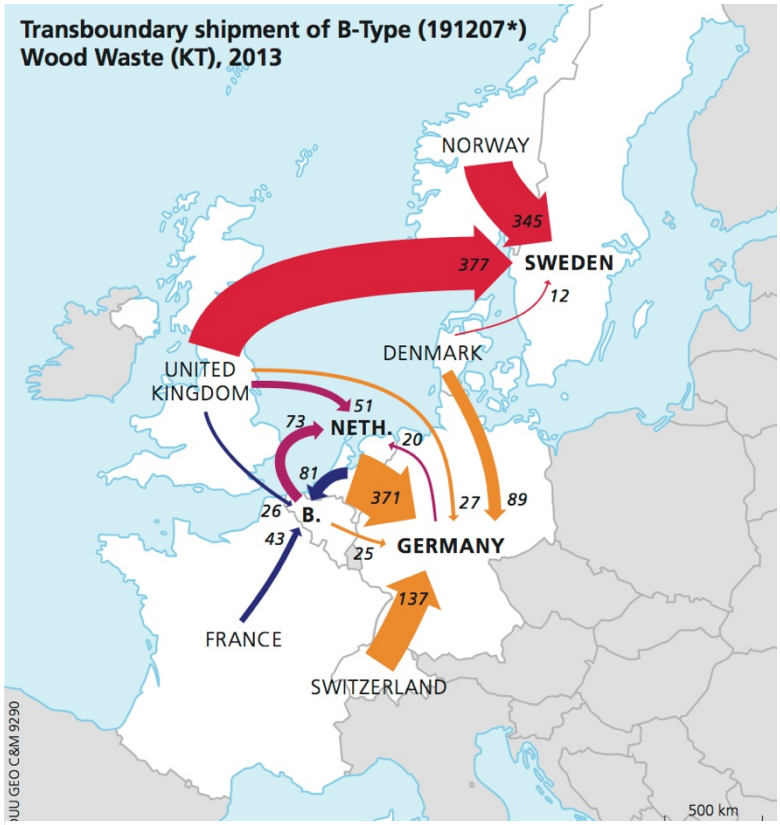


Figure 19 Transboundary shipment of B type Wood Waste, 2013

The total trade of wood waste increased to 1721 KT in 2014. Sweden was the top importer with 736 KT of wood waste imports and Germany imported 618 KT of wood waste. As seen in the map for 2014, UK has started reducing the wood waste exports to Sweden as well as Germany. UK planned to start new biomass plants from 2015 and hence the capacity for wood waste energy recovery increased in the country. The wood waste is going to be used for energy recovery purposes in UK.

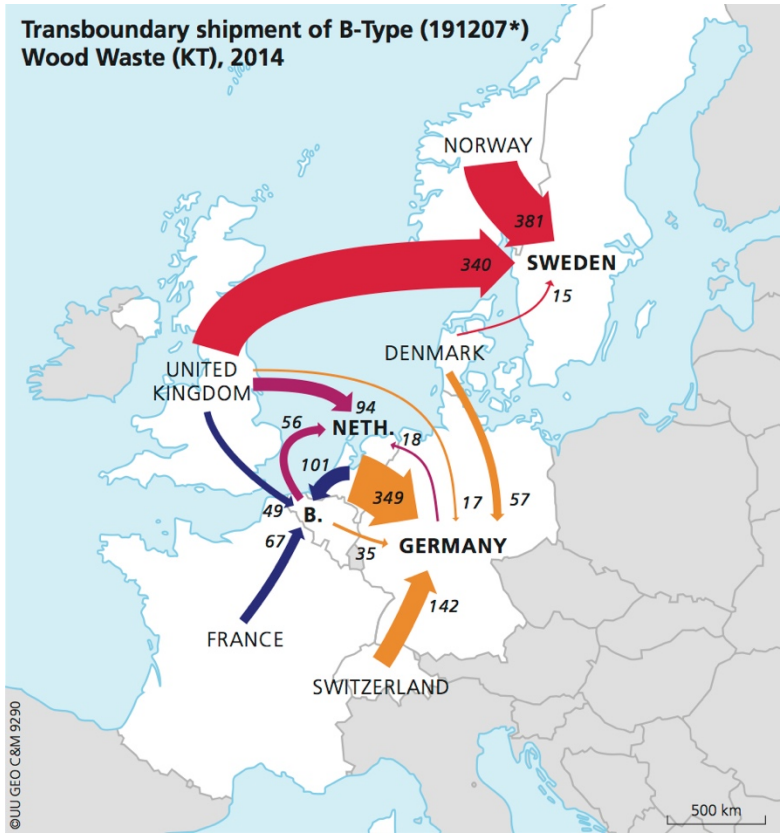


Figure 20 Transboundary shipment of B type Wood Waste, 2014

The trade of wood waste remained constant in 2015 at 1722 KT. There are major factors for this constant supply of wood waste in 2015. In Germany, majority of the power plants are old and retiring in 2019. Hence, the supply of wood waste in Germany has been nearly constant at 633 KT. The supply of wood waste to Sweden reduced drastically to 685 KT because of reduction of imports from the UK. The reason for reduction is the installation of new bioenergy plants in UK.

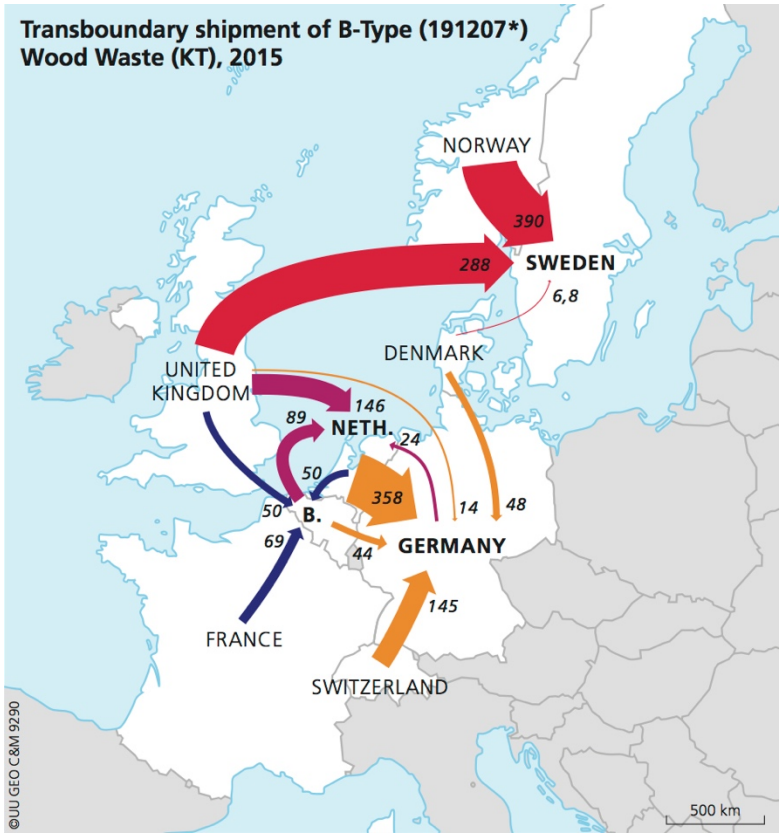


Figure 21 Transboundary shipment of B type Wood Waste, 2015

### 4.5.2. HAZARDOUS WOOD WASTE (191206*)

The hazardous wood waste with EWC 191206* is transported mainly to Germany in Europe. Germany has a robust legislation system which helped in developing a strong biomass industry. It is one of the countries which accepts hazardous wood waste and can incinerate it whether for energy or non-energy purposes. Sweden, is another net importer of hazardous wood waste. The most important driver of trans boundary shipment of hazardous wood waste is legislation. In UK, there is no provision for shipment of hazardous wood waste and hence majority of it is landfilled which is ultimately harmful for the country. Germany on the other hand, has provisions for incineration of hazardous wood waste and hence is the largest importer of hazardous wood waste in Europe. One of the largest exporter of hazardous wood waste is the Netherlands. It has no provisions in its legislation for landfilling the hazardous wood waste. Although, it does have the provision to incinerate the waste, but it should follow proper protocol and hence the whole process becomes costlier. Therefore, it is cheaper for the Netherlands to export its hazardous waste to the neighboring country, Germany. According to the EU directives and regulations, the landfilling of hazardous wood waste is not allowed and it has been adopted by many countries in Europe. Hence, the only way to dispose off hazardous wood waste is by incineration, whether for energy purposes or non-energy purposes. The plant should follow proper limits of pollutants released on incineration of hazardous wood waste and hence it can be a costly option. The general trend of shipment of hazardous waste is decreasing over the years because of stricter rules and policies in every country.

In 2010, 285 KT of hazardous wood waste was transported in Europe out of which 263 KT were imported to Germany. Sweden imports hazardous waste wood mainly from Norway, because it lacks the capacity to handle the hazardous wood waste and the landfilling ban in Norway avoids it to landfill the hazardous waste, hence it exports majority of the hazardous wood waste to Sweden.

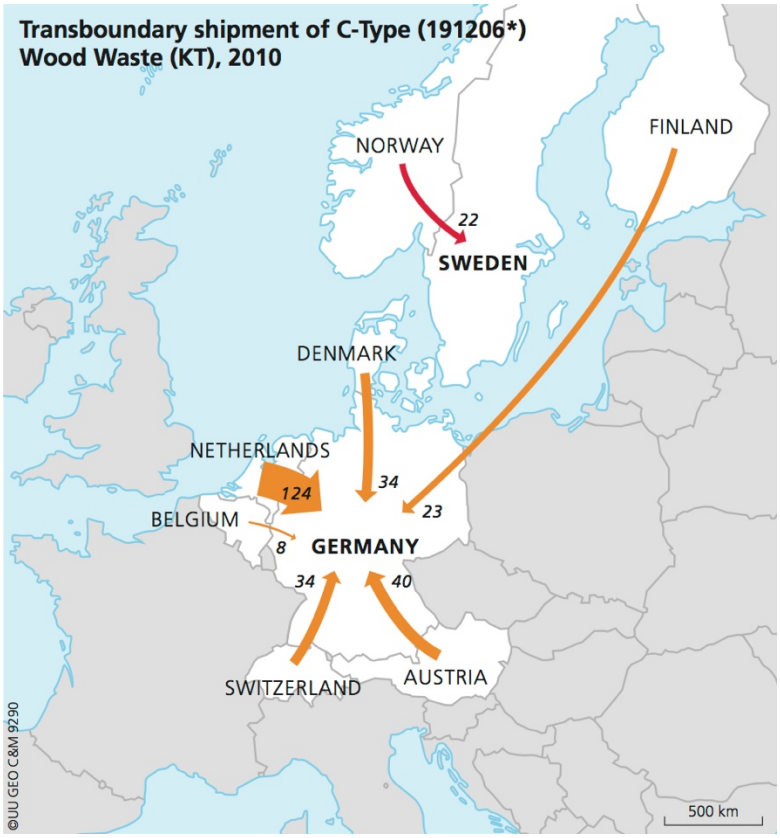


Figure 22 Transboundary shipment of C type Wood Waste, 2010

In 2011, 299 KT of hazardous wood waste was transported in Europe out of which 269 KT was imported to Germany. Germany acts as a one of the key players in driving the hazardous waste wood trans boundary shipment. It imports hazardous wood waste from all the neighboring countries including Switzerland and Austria.

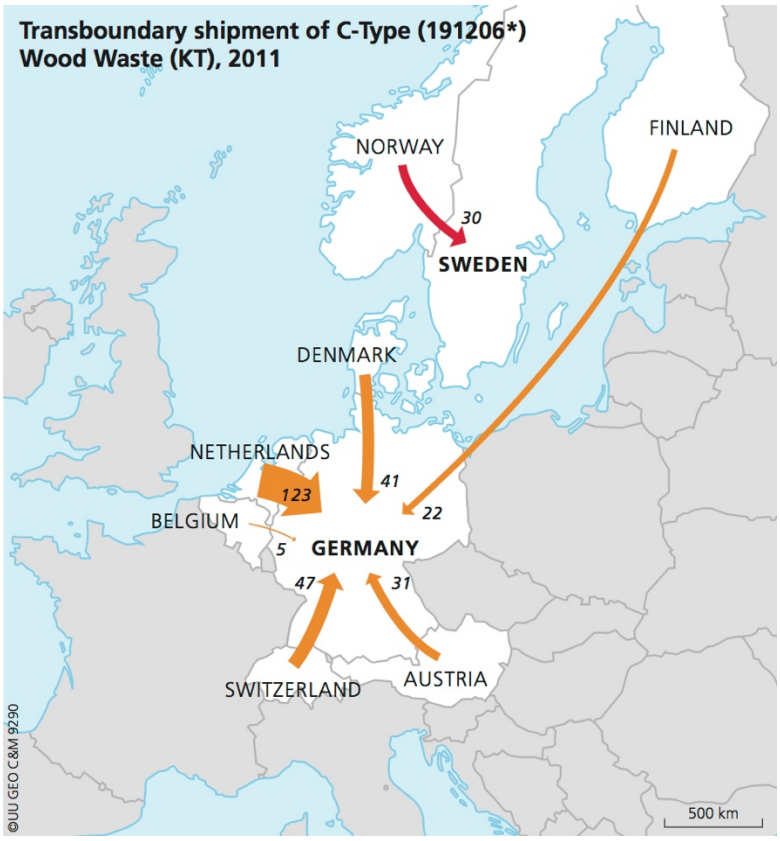


Figure 23 Transboundary shipment of C type Wood Waste, 2011

In 2012, 254 KT of hazardous wood waste was transported in Europe with more than 90% being imported to Germany. As it can be seen, the total shipments are decreasing every year, indicating the application of a stronger legislation in countries like The Netherlands, where in many hazardous waste, were infact found out to be non-hazardous and converted to those shipments.

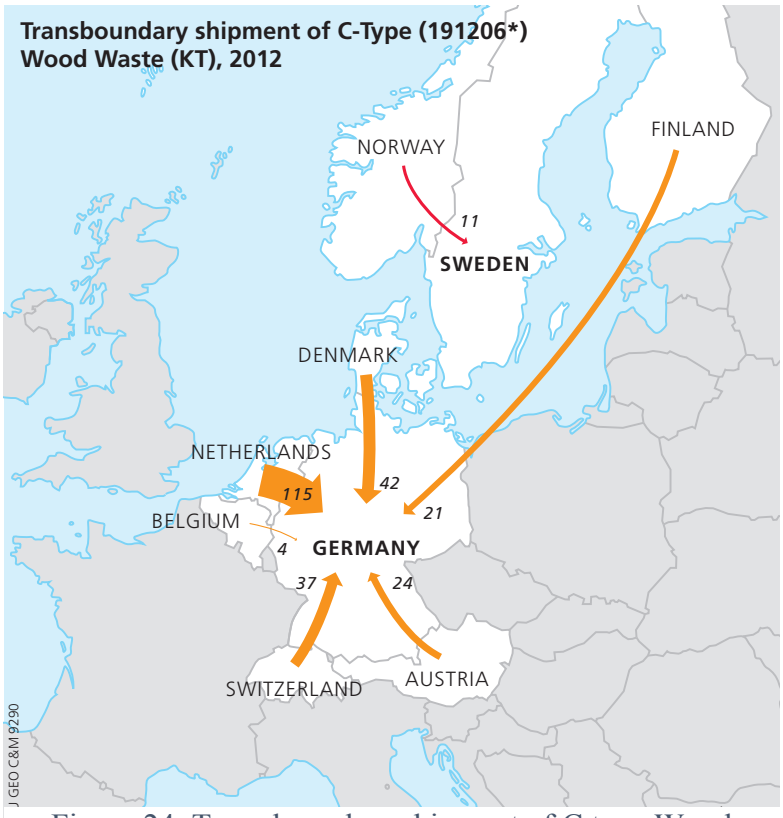


Figure 24: Trans boundary shipment of C type Wood Waste, 2012

In 2013, 233 KT of hazardous wood waste was transported in Europe. Since 2012, the hazardous wood waste shipments dropped even further. Germany still remains the top importer.

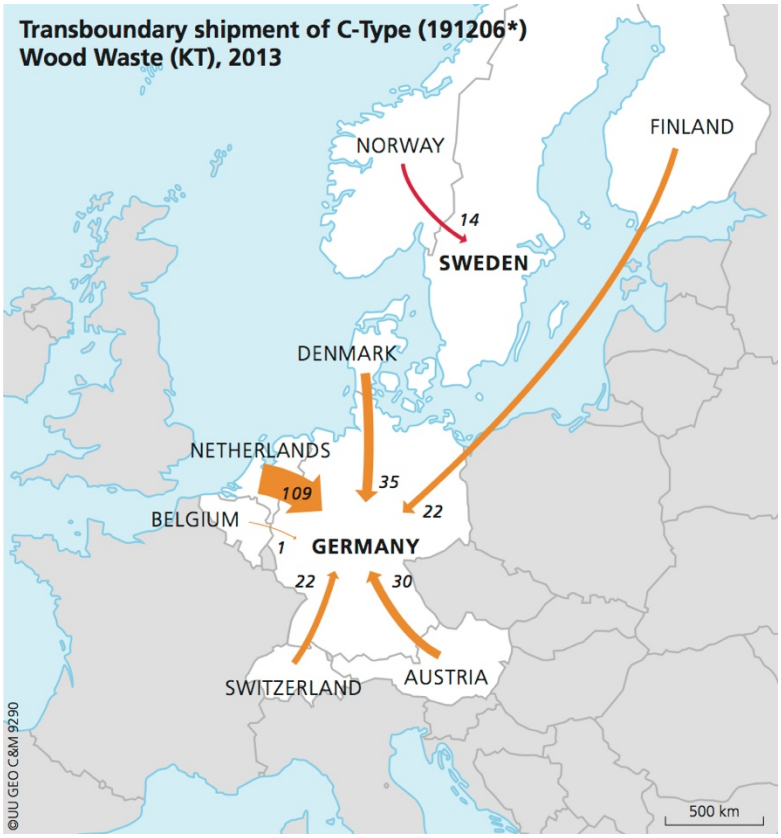


Figure 25 Transboundary shipment of C type Wood Waste, 2013

In 2014, 240 KT of hazardous wood waste was transported in Europe. The hazardous wood waste can't be treated by countries like Denmark and Austria, since they lack the capacity to deal with hazardous wood waste. The legislation doesn't allow to landfill hazardous waste and hence it is exported to Germany.

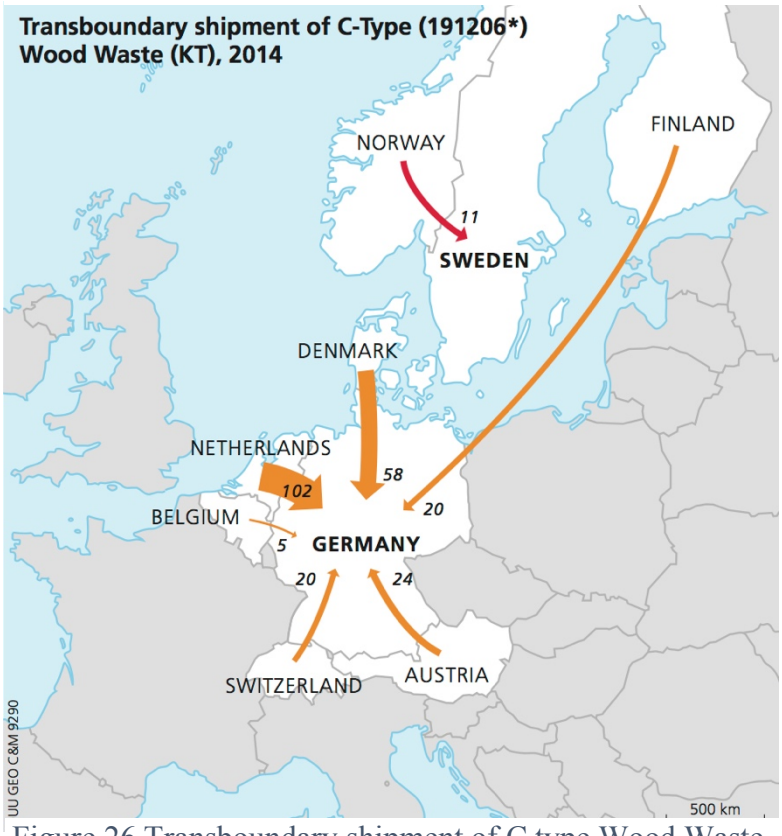


Figure 26 Transboundary shipment of C type Wood Waste, 2014

In 2015, 262 KT of hazardous wood waste was transported in Europe. This is because of increase in hazardous wood generation in The Netherlands and its inability to recover energy from the same. Norway has landfill bans but lacks the capacity to deal with the upsurge of hazardous wood waste and hence has to transport it to Sweden, which is cheaper than incineration.

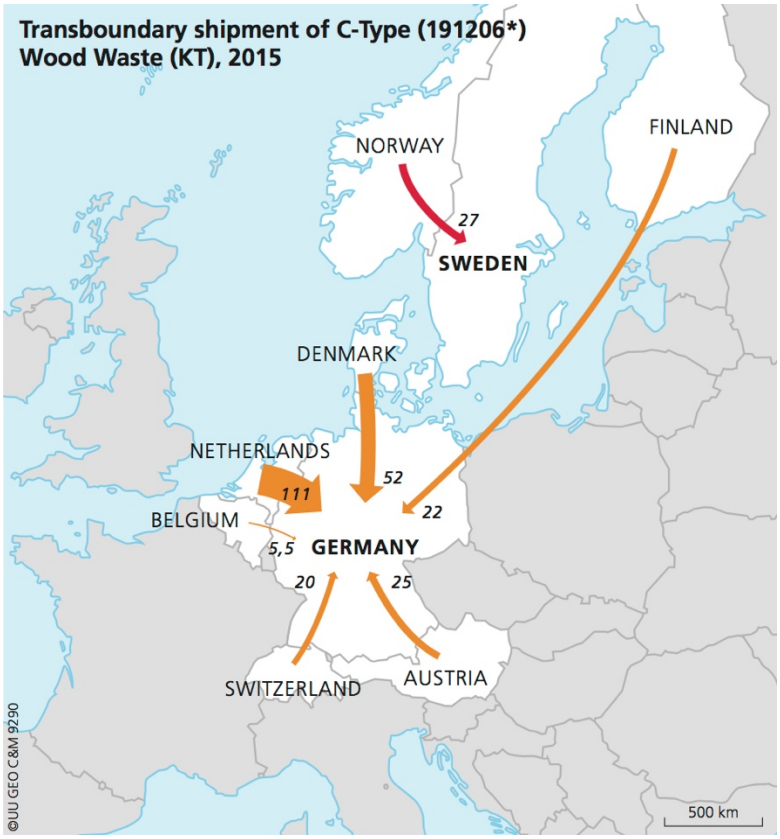


Figure 27: Transboundary shipment of C type Wood Waste, 2015

# 5. DISCUSSION

## 5.1. DRIVERS OF TRANS BOUNDARY SHIPMENT OF WASTE WOOD

### 5.1.1. HAZARDOUS WOOD WASTE

There has been a constant demand and supply for hazardous wood waste across the EU. There are various factors that are driving the trans boundary shipment of waste wood. The major drivers are as follows:

1. Legislations and Policies: One of the most important driver is the legislations and policies that a country imposes on the recovery options of hazardous wood waste. As it can be seen in the section above, Germany is the highest importer of hazardous wood waste and it acts like a sink for Europe's hazardous wood waste. It has been made possible because of the detailed policies that have been adopted by the federal as well as state governments over the year. Germany was the one of the first countries to have a hazardous waste ordinance. It also implemented the renewable energy sources act and electricity from biomass act making it easier for the biomass plants to run. It has a special waste wood management ordinance which takes care of the recovered and used wood exclusively. Hence, promoting better standards and greater market equality. Therefore, it is proven that legislation plays an important role in the trans boundary shipment of the wood waste.

2. Capacity Factor and Technology: They play another important role in driving the trade. The lack of capacity of the exporting countries combined with the need to feed existing treatment capacities of the importing countries can drive the trade of hazardous wood waste. For example, The Netherlands does not have the legislation or the capacity to deal with the hazardous wood waste and hence is solely dependent on Germany for getting rid of it. On the other hand, Germany requires all the wood waste it can get to keep the treatment facilities with constant feedstock for its 700 bioenergy plants, approximating at 1000 MW as shown in the figure below. (DBFZ, 2015) The technology also drives a lot of hazardous wood waste. Even though The Netherlands might have the capacity, it must have the best technology possible to use hazardous wood waste for energy recovery purposes which is in accordance with the strict Dutch legislation. (VROM, The Netherlands, 2004)

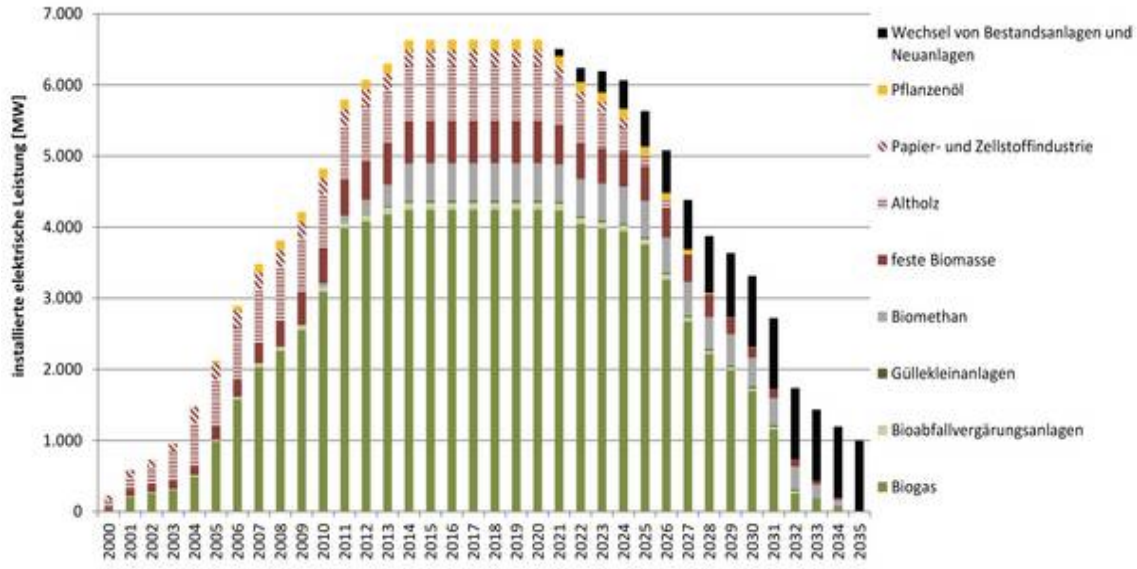


Figure 28: Installed capacity in Germany over the years. Source: *(DBFZ, 2015)*

3. Economics: In many countries, it is costlier to dispose off the waste in landfills than trade it to another country. Except UK, The Netherlands, Germany and Sweden all have a certain disposal tax, if the waste is being landfilled. In some cases, it is totally prohibited. These cost restrictions drive the trans boundary shipment of hazardous wood waste. Also, sometimes the wood waste is a cheaper fuel than the contemporary wood pellets or regular fuel in the market and hence the demand for wood waste as a fuel increases and a market of wood waste drives the trans boundary shipment of hazardous wood waste.

Table 5: Landfilling Tax in European Countries (Source: (CEWEP, 2017))

| Country | Landfill Tax | Landfill Ban Implemented |
|---|---|---|
| **Germany** | - | Landfill ban for untreated MSW since 1.6.2005 |
| **Sweden** | Average net fee for landfilling: €50-75/t<br><br>Landfill tax: €55/t (increased from €45/t in 2015)<br><br>Total price for landfilling: €120-170/t<br><br>Landfill tax increased more than 50% from 2001 to 2010 | 1.1.2002: Sorted combustible waste<br><br>1.1.2005: Organic waste |
| **The Netherlands** | 17 €/t (2014)<br><br>Average net price: 40 – 50 €/t | For 64 categories of waste |
| **UK** | 2.65 – 84.4 £/t<br><br>Gate fees: 9-25£/t (10.40-29 €/t) | NO |

4. Transportation: The transport to neighboring country is another added factor. As seen in the maps, the waste is being traded with the neighboring countries indicates that the transportation costs also matter. Sometimes, the facilities in another country might be closer to reach than the facilities in their own country. But, with transportation, the environmental impacts should also be calculated. According to a study by Olofsson et al, it can cost 40 euros/ ton to transport mixed waste in Germany where as it costs 52 euros/ton to transport mixed waste in Denmark. This difference is because of variation in type of transport used for shipment of waste, like a truck and a boat. Transportation by boat costs lesser than a truck. (Mattias Olofsson, 2005)

### 5.1.2. NON – HAZARDOUS WOOD WASTE

1. Legislation and Policies: For non-hazardous waste, the legislation becomes a very important driver. As mentioned in the EU WFD, non-hazardous waste wood can either go for material or energy recovery. Hence, one more market of recycling industry opens for non-hazardous wood waste along with the biomass plants. In the Netherlands, the government has planned to consider a mandate which makes co – firing compulsory for the coal plants and wood waste is generally used as a feedstock. (Pellcert, 2012)
   In UK, the government provides financial support in the form of Renewable Obligation Certificates. In Germany, the detailed legislation is already discussed in chapters above which make the market for non – hazardous wood waste favorable. Hence, the legislation is an important driver for the trans boundary flow of wood waste. (NL Agency, NL Energy and Climate Change, 2013)

2. Capacity Factor: The capacity factor also plays an important role. As seen in the case of Germany as well as The Netherlands, higher the number of wood waste biomass plants, higher are the imports. The Netherlands did not import B type wood waste until 2012 when it opened the highest capacity wood waste biomass plant, Eneco and the imports eventually increased in the upcoming years from United Kingdom as well as other countries and decreased to the neighboring countries since it was being used for national energy production. The high capacity factor of Germany and Sweden drives a B – type wood waste from neighboring countries.

3. Price of Waste Wood: In UK, the wood waste market is highly dependent on the cost of waste wood. The lower grade wood waste has a lot of cost associated with it such as cleaning and the costs add up because of the governmental policies like landfill tax which lowers the demand for hazardous wood waste. High grade wood waste, or non-hazardous wood waste do not face such issues. (NL Agency, NL Energy and Climate Change, 2013)

Table 6: Cost of disposal of wood (Source: (DEFRA, 2008))

| GRADE | RECOVERY METHODS | RECOVERY COST |
|---|---|---|
| **GRADE A** | Animal Bedding, Mulches, Panel board | Potential income of £150 |
| **GRADE B and C** | Energy or Panel Board | Cost to £5 to £30 |
| **GRADE D** | Landfilling | £35 to £45 |

## 5.2. FUTURE TRENDS

The future trends in the import and export of wood waste is obtained from interviews from experts in UK, The Netherlands, Germany and Sweden. UK has decided to increase the bioenergy capacity in the upcoming years and the main feedstock for the bioenergy plants would be industrial grade wood waste. Considering it is a major exporter of wood waste to countries like Sweden, The Netherlands and Germany, it aims to reduce the exports in the upcoming years. While, Sweden can manage the feedstock supply from wood pellets and different sources of biomass, The Netherlands and Germany have to look for new exporters of B type wood waste to keep its bioenergy plants like Eneco supplied with a constant feedstock. UK also considers to export in the upcoming years, if the installation of new bioenergy plants is successful. It has to be noted that Brexit does not affect the shipment flows of wood waste currently or in the upcoming years, according to multiple experts from UK and other countries.

Germany has around 1000 MW bioenergy plants installed and working currently, but many plants are old and in the process of retiring. The plants plan to phase out by 2019-2021. It also intends to change the legislation around 2020. The capacity would drastically reduce in the upcoming years, if new plants are not introduced in Germany. The capacity reduction will have an immediate effect on the hazardous wood waste of Europe since Germany behaves like a dumping ground for hazardous wood waste in Europe. The Netherlands would be affected the most, since it is constantly exporting 100+ KT of hazardous wood waste every year to Germany along with 350+ KT of non hazardous wood waste/year. The Netherlands would require to reform the legislation or introduce bioenergy plants with better flue gas cleaning systems.

The Netherlands has to find new exporters for maintaining a constant feedstock for its bioenergy plants in the upcoming years. It has started facing problems currently when UK reduced the exports of 191207 wood waste to The Netherlands. It also has to find new importers for its hazardous wood waste generation since Germany would reduce its imports in the years to come.

## 5.3. UNCERTAINTIES AND METHODOLOGICAL CHALLENGES

The national reports on the Basel International website provides a great deal of insight on the production, import and export of different kinds of hazardous as well as non hazardous waste. But still, there were considerable variability in certain data sets available. The following sources of uncertainties have been identified during the study:

(a) Lack of availability of data: Apart from the national reports on the trans boundary shipment of waste by Basel International, the sources of data available online is limited. The data provided by Eurostat has shown high levels of unreliability and confirmed by ministry officials of The Netherlands and Sweden. The data for CN Code system is not up to date. There is a lack of an online statistical dataset solely based on the European Waste Codes. An EWC list centric dataset could be beneficial for a better and faster approach to the trans boundary flow studies in the future.

(b) Inconsistency in different codes: This was one of the major issues while collecting statistics for the study. As mentioned in the data collection part, the study encountered multiple code systems in Europe. The description of the trade commodities was different in different code systems. This led to difficulty in selecting a common and uniform code system. The EC has addressed the issue and is working on co relating the code systems which can be a huge help for the future studies.

(c) Redundancy of data: Since the data was procured from more than one source, this led to varied datasets that overlapped. The datasets were thoroughly checked for redundancy and double data.

(d) Difference in data from different countries: There is a slight difference in the import and export values of different countries. The value that is being exported is minutely different than the value that is being imported. Since the difference is not huge it has been seen as a positive characteristic of the dataset being accurate.

# 6. CONCLUSION

The hazardous and non hazardous wood waste have a prominent shipment flows in Europe, especially in North Western Europe. Germany and Sweden are the most important countries driving the trans boundary flows of wood waste in Europe.

The major exporters for hazardous waste are The Netherlands and Norway. The main importers for the hazardous waste are Sweden and Germany. Germany acts like a sink for hazardous wood waste in Europe. Every year it imports average 230 KT of hazardous wood waste to incinerate at its bioenergy facilities. Sweden imports from Norway at an average rate of 25 KT a year. From 2010 till 2015, there is a general trend of declination of shipment of hazardous waste because of new and stricter legislations and policies in every country regarding hazardous waste. This trend is going to continue in the upcoming years.

The non hazardous wood waste is an ideal industrial grade feedstock for bioenergy plants in Europe and hence is a contender to the conventional biomass trade. It gives direct competition in terms of prices, since it can be cheaper than normal wood chips as a fuel. It is being traded extensively throughout Europe but the major countries to participate in the trade are situated in the North Western area. UK, The Netherlands and Norway are main exporters of non hazardous wood waste with an average export of 300+KT every year whereas Sweden, Germany and The Netherlands are main importers with and average imports of 600+KT every year.

The key drivers identified in both the cases are a strong legislation and a robust capacity to handle the incoming wood waste for energy recovery purposes. The countries with huge imports have these key drivers in common. With Germany, the legislation is detailed and promotes the installation of bioenergy plants, hence giving platform for better capacity. In Sweden, the capacity is in the form of CHP plants and it is accepting wood waste as a feedstock from neighboring countries.

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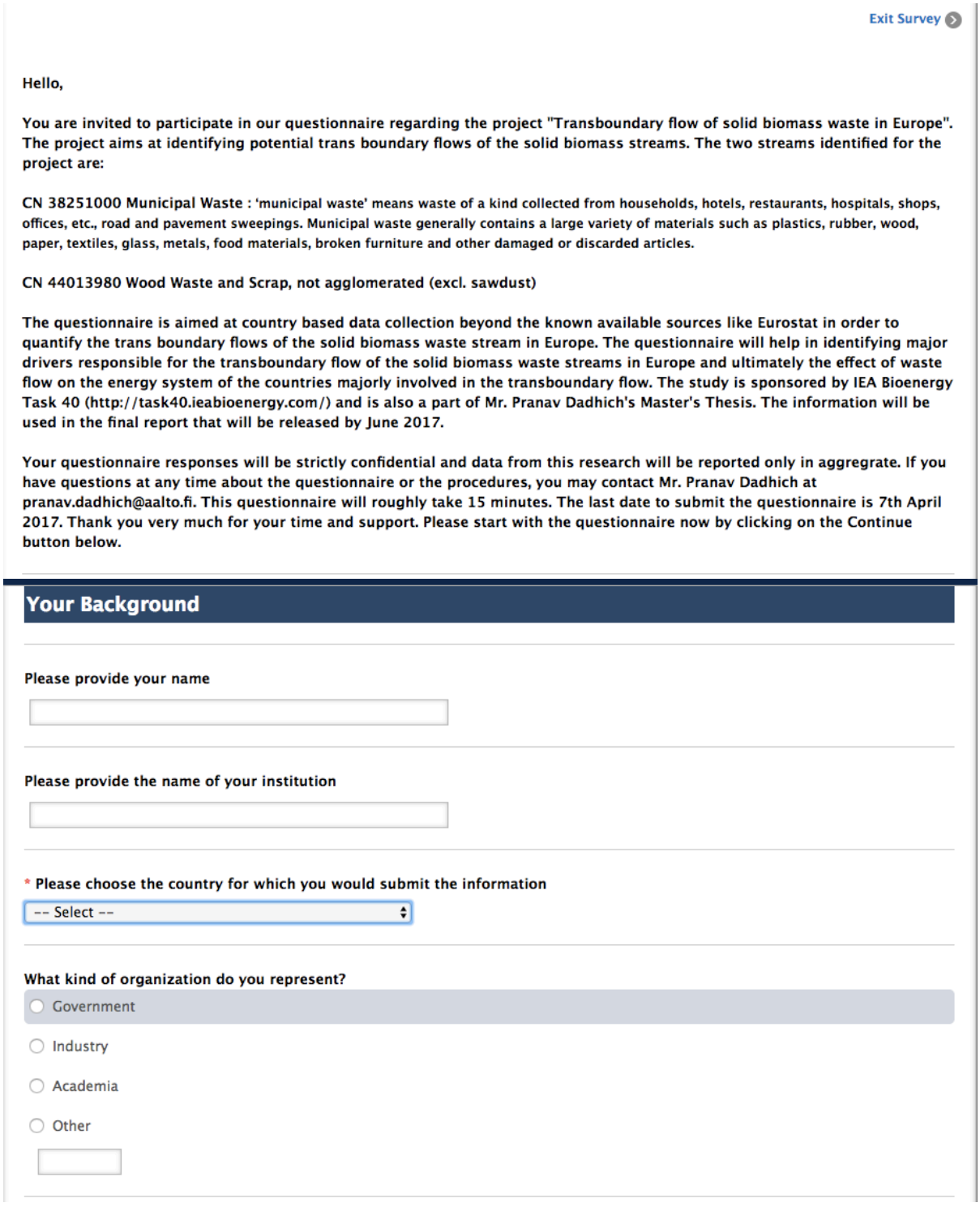
# ANNEX

Questionnaire for IEA Task 36 and 40 members
Link to the survey : http://ieabioenergytask40.questionpro.com/



Exit Survey

Hello,

You are invited to participate in our questionnaire regarding the project "Transboundary flow of solid biomass waste in Europe". The project aims at identifying potential trans boundary flows of the solid biomass streams. The two streams identified for the project are:

CN 38251000 Municipal Waste : 'municipal waste' means waste of a kind collected from households, hotels, restaurants, hospitals, shops, offices, etc., road and pavement sweepings. Municipal waste generally contains a large variety of materials such as plastics, rubber, wood, paper, textiles, glass, metals, food materials, broken furniture and other damaged or discarded articles.

CN 44013980 Wood Waste and Scrap, not agglomerated (excl. sawdust)

The questionnaire is aimed at country based data collection beyond the known available sources like Eurostat in order to quantify the trans boundary flows of the solid biomass waste stream in Europe. The questionnaire will help in identifying major drivers responsible for the transboundary flow of the solid biomass waste streams in Europe and ultimately the effect of waste flow on the energy system of the countries majorly involved in the transboundary flow. The study is sponsored by IEA Bioenergy Task 40 (http://task40.ieabioenergy.com/) and is also a part of Mr. Pranav Dadhich's Master's Thesis. The information will be used in the final report that will be released by June 2017.

Your questionnaire responses will be strictly confidential and data from this research will be reported only in aggregrate. If you have questions at any time about the questionnaire or the procedures, you may contact Mr. Pranav Dadhich at pranav.dadhich@aalto.fi. This questionnaire will roughly take 15 minutes. The last date to submit the questionnaire is 7th April 2017. Thank you very much for your time and support. Please start with the questionnaire now by clicking on the Continue button below.

Your Background

Please provide your name

Please provide the name of your institution

* Please choose the country for which you would submit the information

-- Select --

What kind of organization do you represent?

Government

Industry

Academia

Other

## Trans Boundary Flow Information

**This section of the questionnaire aims at collecting country specific information on the trans boundary flow of solid biomass waste streams. You can submit relevant links to papers or organizations responsible wherever necessary.**

*** Is there any national database/publications on trans boundary flow of waste in the national language or English?**

- ○ Yes
- ○ No
- ○ Don't Know

**According to the response of this question, the further questionnaire will be set. Which field would you like to answer the questions about?**

- ○ MSW
- ○ Wood Waste
- ○ Both of the above
- ○ General Expertise

**Were there any changes in legislation regarding trans boundary flow of wood waste in the years 2010-2015 in your country?**

- ○ Yes
- ○ No
- ○ Don't Know

**Were there any subsidies/government benefits regarding wood waste related energy activities in your country in the years 2010-2015?**

- ○ Yes
- ○ No
- ○ Maybe

**Were there any recent developments in the technology sector of energy recovery from wood waste in your country in the years 2010-2015?**

- ○ Yes
- ○ No
- ○ Don't Know

**Was there any reform in waste management sector especially regarding wood waste in your country in the years 2010-2015 regarding wood waste?**

- ○ Yes
- ○ No
- ○ Don't Know

**What is the end use of wood waste?**

- ○ Energy Recovery
- ○ Disposal
- ○ Recycling
- ○ Other

## Drivers of transboundary flow of waste

**According to you, which is the most important driver for the growing trans boundary flow of waste in Europe? You can choose more than one driver.**

**Please select the most important driver for trans boundary flow of waste in Europe:**

| | Wood Waste |
|---|---|
| Gate fees | ☐ |
| Disposal costs | ☐ |
| Legislations and Policies | ☐ |
| Capacity Factor | ☐ |
| Governmental Incentives | ☐ |
| Technology | ☐ |

**Apart from all the drivers listed above, what other drivers do you feel can be responsible for the trans boundary flow of wood waste in Europe?**

## Thank you for your feedback

**Would you like to receive the result of this questionnaire?**

- ○ Yes
- ○ No

**Can you give contact details of any experts in the field of Trans Boundary flows of Wood Waste or MSW from your country?**

- ○ Yes
- ○ No

**Can we approach you by email for follow up questions?**

- ○ Yes
- ○ No